FORECASTING POTENTIAL PROJECT RISKS THROUGH LEADING INDICATORS TO PROJECT OUTCOME

A Thesis

by

JI WON CHOI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2007

Major Subject: Civil Engineering

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Chair of Committee, Stuart D. Anderson
Committee Members, James C. Smith
Seth Guikema
Head of Department, David Rosowsky

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ABSTRACT

Forecasting Potential Project Risks through Leading Indicators to Project Outcome. (May 2007)

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During project execution, the status of the project is periodically evaluated, using traditional methods or standard practices. However, these traditional methods or standard practices may not adequately identify certain issues, such as lack of sufficient identification of warning signs that predict potential project failure. Current methods may lack the ability to provide real time indications of emerging problems that impact project outcomes in a timely manner.

To address this problem, the Construction Industry Institute (CII) formed a research team to develop a new tool that can forecast the potential risk of not meeting specific project outcomes based on assessing leading indicators. Thus, the leading indicators were identified and then the new tool was developed and validated.

A screening process was conducted through industry surveys after identifying potential leading indicators. Each time, industry professionals were asked to evaluate the negative impact of leading indicators on project outcomes that were identified to measure the impact of leading indicators on project health. Through this process, forty

three leading indicators were acquired finally. Using descriptive statistics, the amount of negative impact of each leading indicator on project outcomes was identified after the analysis of the survey results. Based on these impacts, the tool development was initiated.

The tool concept is that no indication of problems based on assessing leading indicators results in the tool output score high. To comply with this concept, specific weights were assigned to each leading indicator to reflect the impact on each project outcome. By this procedure, the Project Health Indicator (PHI) tool was developed. The validation process of the PHI tool was conducted using completed projects and finally negative correlation was observed between project outcomes and health scores generated by the PHI tool.

DEDICATION

To God the Almighty the Heavenly Father who has given me the Knowledge to do this and showed me so much Love. All Glory be to God on High.

ACKNOWLEDGMENTS

First of all, I would like to thank God, my Lord and Savior, for giving me Knowledge, Strength, and Perseverance in my studies. Without Him none of this would be possible.

I would like to address special thanks to my advisor Dr. Stuart D. Anderson for giving me a chance to perform this research, his advice, and constructive criticism that helped me a lot to complete this research. I thank all nineteen research team members who have spent countless time for this research sharing their knowledge and experience from the field. I would also like to thank Dr. James C. Smith and Dr. Seth Guikema for their extensive comments that enabled me to improve the research.

I also thank my beloved wife and children: Yangsun, Inyoung, Isaac, and Priscilla, for their love and support during my study. Last but not least, I would like to thank all who prayed for me.

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CHAPTER I

INTRODUCTION

1.1 Background

As suggested by the Construction Industry Institute (CII), a project is developed through a cycle that includes front end planning and project execution (CII 1994). Project execution includes detailed design, procurement of materials and equipment, construction, and startup. Typically, in the early project phases, during front end planning, project management focuses on practices that have a substantial impact on changing project outcomes, as suggested by the CII influence curve (CII 1994). As the project moves into execution, the ability to influence project outcomes diminishes; the emphasis then shifts to managing project work to ensure the desired project outcomes are achieved.

1.2 Problems

During project execution, the status of the project is periodically evaluated, using traditional methods or standard practices. Indicators, such as a performance ratio, schedule variance, and cost variance are measured to provide hard data on a project's current status and progress. Based on the evaluation of these indicators, the project health is determined. However, these indicators and their measures may not adequately

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This thesis follows the style and format of *Journal of Construction Engineering and Management*.

identify certain issues, such as lack of sufficient identification of warning signs that predict potential project failure, lack of an early method to show that a project is on the right track, and lack of connectors that can fill the gaps between the traditional methods and the degree to which the project is “on-the-right-track.” Current methods may lack the ability to provide real time indications of emerging problems that impact project outcomes in a timely manner.

In fact, there are likely other non-traditional indicators that, perhaps, provide a clearer picture of how and where a project has gone off course. These non-traditional indicators (called “Leading Indicators” in this research) may have a significant impact on project outcomes. Currently, there is no methodology or tool available to assess the impact these non-traditional indicators have on project outcomes.

As a result, the Construction Industry Institute (CII) funded a research effort titled, “Leading Indicators to Project Outcome,” to address this specific issue. Thus, the work behind this thesis was funded through a research grant from the CII. Nineteen industry professionals from CII member companies were formed as a research team for this project by CII.

The team members were upper management level people representing various industries such as chemical, petroleum, construction, pharmaceutical, and manufacturing. The team consisted of eight owners and ten contractors including three purely engineering firms. These members were asked to assist in conducting this research giving comments and advice, and participating in surveys performed for this research. They are called research team members hereafter.

1.3 Research Goal and Objectives

The primary goal of the research is to develop a new tool that can forecast the potential risk of not meeting specific project outcomes based on assessing leading indicators. This research will be guided by four specific objectives, to:

- identify the leading indicators to project outcome during project execution,
- determine which leading indicators impact project outcomes to the greatest extent,
- develop a tool for implementing periodic project reviews based on a set of Leading Indicators, and
- validate the tool.

1.3.1 Definition of Terms / Abbreviations

Following are the definition of four terms with a common meaning as used in this research. These two definitions were refined through the research and other definitions of key terms were added as necessary over the course of the study.

- <u>Leading Indicators</u>: Leading indicators are defined as non-traditional methods or practices used to determine the level of "on-the-right-track" of a project during project execution.
- <u>Traditional measures</u>: Traditional measures are conventional methods or standard practices used in the construction industry to evaluate the status of a project periodically.

- Potential risk: Potential risk is the cumulative effect of the chances of uncertain occurrences which will adversely affect project objectives or any factor that may potentially interfere with successful completion of the project.
- Project execution: Project execution refers to the detailed design, procurement, construction, and startup project phases.

1.3.2 Limitations / Delimitations

There are two limitations in performing this research. The first limitation is that the data collection for this research is generally limited to CII member companies. Thus, the projects used in the research will likely be related to the industrial and building construction industries. The second limitation is that the new tool will not measure and quantify a specific amount of risk for a project, but will forecast the potential risk that certain project outcomes will not be met.

1.4 Report Structure

This report consists of eight chapters. Chapter I introduces the background, problem, and goal and objectives of the research. A review of literature is provided in Chapter II. A brief explanation about the data collection and analysis approach and tool development process are presented including the research hypothesis in Chapter III. Chapter IV presents the detailed process and method of data collection and analysis. Chapter V explains each step of the tool development process in detail. Chapter VI describes detailed features of the developed tool. Finally, conclusions and recommendations for expected future research are discussed in the Chapter VII.

CHAPTER II

REVIEW OF LITERATURE

Despite an extensive search of the literature, few publications related to this subject were located and reviewed. The literature review includes the following subjects:

- leading indicators used for performance measurement,
- measuring influence of leading indicators on project outcome,
- similar type tools used in the construction industry, and
- tool validation methodologies.

2.1 Leading Indicators as Performance Measurement

Traditional performance measures like "return on investment" and "earnings per share" have been used to measure performance of projects, organizations, or groups for decades. Managers have often been dissatisfied with these traditional measures, when measuring organizational performance, and have expressed concern that traditional measures could misrepresent the performance of organizations or groups. As a result, a new measure of performance for an organization or business was needed (Kaplan and Norton 1992). At that time, Kaplan and Norton were aware of this need and developed a "Balanced Scorecard" that could be used in any industry by incorporating non-traditional measures with the existing traditional measures. Examples of non-traditional measures that Kaplan and Norton added were: "How do customers see us?; What must we excel at?; and Can we continue to improve and create value?" (Kaplan and Norton 1992, p. 72).

Although these examples are not directly related to indicators for capital projects within the construction industry, they provide an idea about the nature of non-traditional measures applicable to projects (qualitative and not easy to measure).

Other examples of potential leading indicators can be found from CII research on Pre-Project Planning. This research developed a tool called, "Project Definition Rating Index (PDRI)." Gibson and Dumont identified 70 elements for the PDRI tool (1996). The elements were defined as critical items that should be included in an industrial project's scope definition package (Gibson and Dumont 1996).

The PDRI tool asks evaluators to assess each project element in terms of the level of definition of that element. Although the elements themselves were not considered indicators, evaluating the level of definition of these elements could provide information about future project health. Thus, in this way, the elements could be considered as leading indicators. For example, the PDRI tool asks evaluators to assess whether or not project philosophies for facility reliability, maintenance, and operation have been defined. Measuring this level of definition is an example of a potential leading indicator.

Unfortunately, there is no specific way to identify leading indicators. Further, a defined set of leading indicators for project execution was not found in the literature. Therefore, leading indicators needed to be identified using the expertise of industry professionals similar to the approach that Gibson and Dumont used for identifying the elements included in the PDRI tool.

2.2 Measuring Influence of Leading Indicators on Project Outcomes

There is a lack of relevant literature on this subject other than PDRI research. Because the nature of the elements in the PDRI tool is likely to be similar to that of leading indicators, the method used for the PDRI research may be applicable to this research. Gibson and Dumont used industry expertise to measure the influence of the 70 PDRI elements on project success. They hosted two workshops, invited construction professionals, and asked them to evaluate each element based on their past experience (1996).

Each element has a five point scale from complete definition to incomplete or poor definition. Depending on the definition scale, Gibson and Dumont asked participants to determine the potential influence of each element on a project's total installed cost estimate stated as a percent of the overall cost (1996). Participants were formed into small teams and each team evaluated all 70 elements. This effort was used to weight each of the 70 elements. The data analysis for the PDRI tool included normalizing the weights using a scale of 1000 points. Thus, all the answers (in the form of a percentage) related to the lowest level of definition for each element were summed and that total was divided by 1000 to generate the ratio for normalization. Multiplying each element's answer by the ratio produced a normalized weight for that element. Gibson and Dumont used 1000 points to clarify the weighting process and help users understand easily the PDRI score when used in practice (1996).

There is one consideration when assessing the impact of leading indicators with respect to project outcomes. The PDRI research team assessed the impact of each element on the cost outcome only, but in this research, the impact of each leading indicator will be assessed on various outcomes, including cost, schedule, quality, safety and customer satisfaction. Using the expertise of construction professionals is imperative to determine the impact of leading indicators on project outcomes. It is necessary to contact professionals with extensive experience in the construction industry, because the more experienced the professionals, the more reliable their answers. Although Gibson and Dumont emphasized the benefits of holding workshops for data collection, all possible means to collect data were considered for this research.

After identifying leading indicators, the impact of leading indicators on project outcomes are evaluated with a scale so that a weight for each leading indicator can be estimated. The idea of normalization and using the scale of 1000 points is considered as well. The overall process of measuring the influence of leading indicators on project outcomes turned out to be quite similar to that of PDRI and thus, many of the steps followed by the PDRI research are adopted in this research, as appropriate.

2.3 Tools Used in the Construction Industry

As noted above, the main objective of this research is to develop a new tool that can forecast the potential risk of not meeting specific project outcomes based on leading indicators. Several tools developed from past CII research provided guidance for developing a new tool for leading indicators. Three of these tools are the PDRI tool, the Alignment Thermometer tool, and the Project Delivery and Contract Strategy (PDCS) tool. Brief descriptions of the three tools follow. The PDRI tool was developed through the research as described above to provide a means to evaluate the scope status of a project during front end planning and to determine a score that corresponds to a project's level of definition (Gibson and Dumont 1996).

The Alignment Thermometer tool was developed to measure project team alignment by generating scores, then specifying areas needing focus by analyzing the scores so that users can track team progress toward alignment (CII 1997). The PDCS tool is the latest tool among the three. This tool is a decision support tool that uses Excel spreadsheets. Based on the user's selection of criteria that would best achieve the owner's project objectives, the tool presents the user with the three most beneficial project delivery and contract strategy alternatives from 12 proposed PDCS alternatives (CII 2003).

The simple structure of these three tools is similar. For the PDRI and Alignment Thermometer tools, users input data (answer a question), then they calculate the input data manually to obtain results (Gibson and Dumont 1996; CII 1997). For the PDCS tool, once a user inputs data, the tool makes the necessary calculations automatically and then generates results (CII 2003). A more specific review of each tool follows.

The PDRI tool is considered one of the most successful tools developed for the industry by the CII. The best feature of the PDRI tool is that it enables project teams to quantify qualitative issues (Whelton 2004). Because the main function of the new tool will also be to quantify qualitative issues, the PDRI tool is a good model to follow for developing a new tool. However, there are a few areas of the PDRI tool that could be improved. The first area of improvement is that users have to calculate the input data by themselves to obtain the result. If a spreadsheet were used for the PDRI tool, it would be easier than the paper based PDRI tool. The other area is that the result of the tool is represented just by a score and it may not be easy for a first time user to understand what the score means. These matters need to be improved, with more user-friendly features like automatic calculations and visualized outputs so that users can clearly interpret the results.

The Alignment Thermometer tool is the simplest of the three tools. The simpler, the better, if wide industry use of the tool is going to be achieved. One advantage of the Alignment Thermometer tool is that the results are represented in graphs, which aid users in understanding the result easily. The other advantage is that users can customize the tool by modifying questionnaires and substituting project specific issues (CII 1997). The new tool needs to incorporate customizable features.

The PDCS tool is the most advanced tool among the three tools. Once a user inputs data then the tool automatically calculates all the output data and generates visual results quickly. Additionally, the tool's features help the user interpret the results, as well as compare PDCS alternatives from the results (CII 2003). These features exist only in the PDCS tool. The PDCS tool uses Microsoft Excel, which is advantageous because most professionals use this application. However, there is one aspect of this tool that could be improved. Although the PDCS tool has very useful features, the user interface design of the tool may need to be improved to increase usability.

2.4 Tool Validation

The validation process of the PDRI tool is discussed in this section, because it is simple and easy to follow. The same process is possibly applicable to the new tool. After developing the PDRI tool, Gibson and Dumont asked professionals who attended the workshops to validate the tool by answering a questionnaire for a past project and evaluating the PDRI tool for project use (1996). In the questionnaire, participants were asked to provide project performance data so that the PDRI research team could compare the PDRI score and project performance (Gibson and Dumont 1996).

Twenty-three various sizes and types of projects were used and the results revealed a correlation between low PDRI scores (meaning project scope is highly defined) and high levels of achieving project performance targets (Gibson and Dumont 1996). The PDRI project team found that projects with less than a 200 PDRI score have a greater chance of achieving performance targets than projects with a PDRI score higher than 200. In other words, a 200 PDRI score was the watershed for differentiating between successful and unsuccessful projects based on the statistical analysis performed during the validation process (Gibson and Dumont 1996).

2.5 Summary

Through the literature review, leading indicators used for performance measurement was explored and an idea of how to identify leading indicators was uncovered. Next, measuring the influence of leading indicators on project outcome was searched and a previous research effort provided an excellent model for this research.

Finally, similar type tools used in the construction industry, and tool validation methods were sought out and discussed. In the next chapter, a brief explanation of the data collection and analysis approach, and tool development process are presented along with the research hypothesis.

CHAPTER III

RESEARCH DESIGN

In this chapter, a brief explanation of the research design is presented. In addition to a general hypothesis behind the research, two major research processes are described using flow charts. These processes are identifying leading indicators and developing a tool using the leading indicators.

3.1 General Hypothesis

The output scores of the new tool positively or negatively correlate to project outcomes such as cost performance and schedule performance. For example, using a negative correlation, if the leading indicator score is low, then the risk of a cost overrun is high.

3.2 Methodology

3.2.1 Data Collection and Analysis Approach

Identifying leading indicators was the first task of the research as stated above. The concept of leading indicators needed to be defined prior to identifying leading indicators. As noted in the definition of terms, leading indicators were initially defined as a non-traditional method or practice used to determine the level of "on-the-right-track" of a project during project execution. Figure 1 summarizes the data collection and analysis processes.

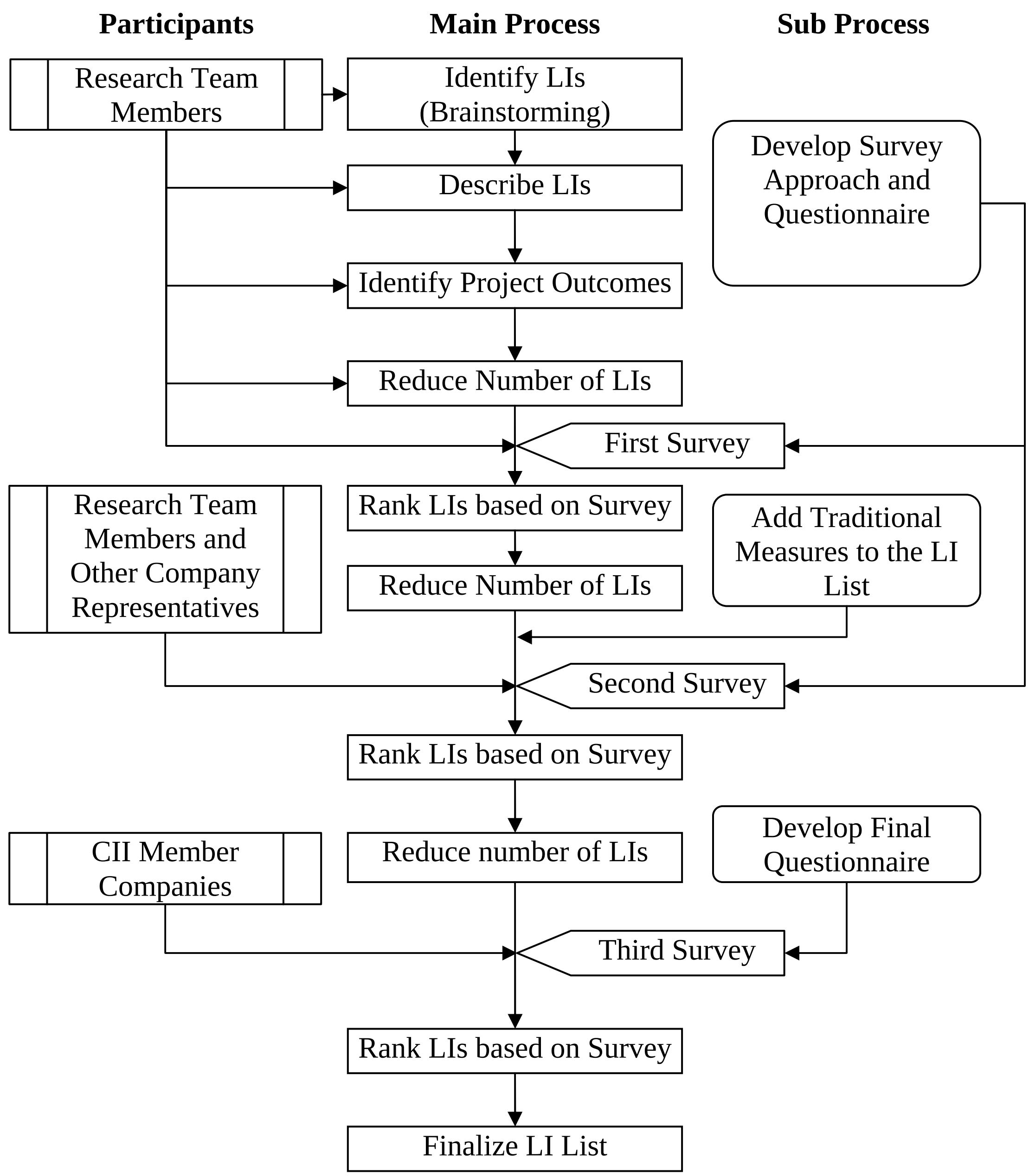


Figure 1. Data Collection and Analysis Processes

To identify leading indicators, the involvement of industry experts was necessary. A group of industry professionals (project managers or similar professionals of CII member companies) was formed as a research team for this project and was contacted and asked to provide potential leading indicators based on their experience (see Appendix A for names and company affiliations). Leading indicators that the industry experts identified were collected. Many times, project managers make decisions and predict results based on gut feelings, intuition, and rules of thumb without any hard data to support these decisions. These intuitive actions were considered when identifying leading indicators. Potential leading indicators were identified. Next, project outcomes were identified to measure the impact of leading indicators on project health.

After gathering all potential leading indicators, a screening process was conducted through industry surveys, with the intent of deleting indicators that had an insignificant impact on project outcomes. Three surveys were conducted with industry professionals. Each time, industry professionals were asked to evaluate the negative impact of leading indicators on project outcomes. The impact of each leading indicator was measured and rank ordered. According to the ranking, leading indicators with less impact on project outcomes were screened out. Through this process, a final list of leading indicators were acquired. This process is discussed in more detail in Chapter IV.

3.2.2 Tool Development

The relationships of leading indicators were established through the collection and analysis of data, and the new tool was developed. Figure 2 summarizes the tool development and validation processes.

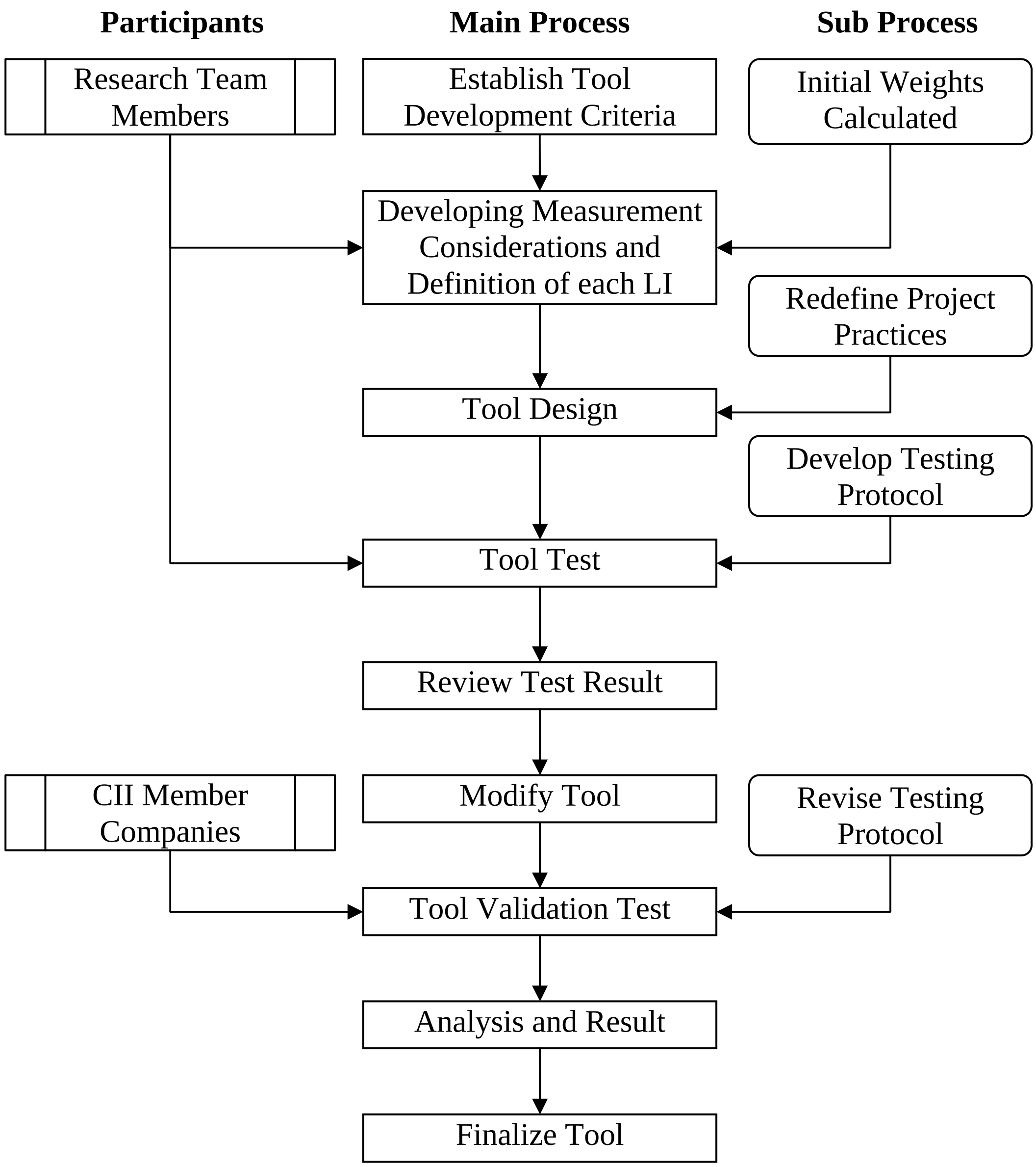


Figure 2. Tool Development and Validation Processes

The prototype of the new tool is similar to the PDRI tool. For example, if there are negative indications based on a leading indicator, such as discord among team members (if a leading indicator is found) during execution of a project, the project outcomes are potentially at risk of not being met. Thus, the tool concept is that if a leading indicator is not reflecting a problem when evaluating a project using the new tool, the tool output score of the project is high. Alternatively, if a leading indicator reflecting a problem when evaluating a project using the new tool the tool output score of the project is low. Adopting this concept, the new tool was developed using a well known application such as the PDRI approach. Using descriptive statistics, the impact of each leading indicator on project outcomes was identified from the surveys performed in the previous stage. Specific weights were assigned to each leading indicator to reflect the impact on each project outcome through statistical analysis. The weighted impacts of leading indicators on project outcomes were normalized to a 1000 point scale. By this procedure, the relationship of leading indicators to project outcomes was assessed.

After developing the new tool, the validation process of the tool was conducted using completed projects. Evaluating different types of projects was preferred and performed. The researcher worked closely with industry in evaluating the new tool to ensure that the tool met the purpose and objectives of this research. The validation method for the new tool followed a similar process to the PDRI tool by comparing statistical correlations between tool output scores and a cost performance index or schedule performance index. This process is discussed in more detail in Chapter V.

3.3 Summary

Brief explanation about data collection and analysis approach, and tool development process were presented along with research hypothesis in this chapter.

Next, a detailed procedure and method to define the final list of leading indicators are discussed and explained in Chapter IV.

CHAPTER IV

DATA COLLECTION

In this chapter, how the leading indicators (LIs) were identified and how the number of LIs were reduced to a final list through three consecutive surveys is explained. Four sections are covered and include identifying leading indicators and project outcomes, the first survey, the second survey, and third third survey. These four sections describe the data collection procedure in detail (refer to Figure 1 in page 18 for an overview of the process).

4.1 Identifying Leading Indicators

4.1.1 Brainstorming of Leading Indicators

To initiate actual data collection, research team members were contacted and provided basic information about this research such as background, problems, goal and objectives, and so on.

To identify LIs, research team members' input from their experience was indispensable. First of all, research team members discussed what defines a leading indicator and then brainstormed potential leading indicators. Each member proposed potential leading indicators and after screening out similar LIs, a total of 181 potential leading indicators were identified. Examples of these early leading indicators are as follows:

- Well-defined project objectives and business goals

- The degree of project objectives knowledge among team members
- Ability/inability to quickly and succinctly articulate main project goals
- Contract change during project
- Change in contracting strategy
- Change in site location

Although some of the leading indicators were vague and unpolished, research members intuitively knew that, in reality, many leading indicators already exist. Numbers were assigned to LIs for easy identification. Appendix B provides the first set of 181 potential LIs with their own numbers.

4.1.2 Definition and Characteristics of Leading Indicators

Definition of leading indicators was necessary to identify LIs from the proposed 181 potential leading indicators. Research team members were asked to define the term. By aggregating the definitions from each team member, the formal definition of a leading indicators was determined as follows:

> "Leading indicators are fundamental project characteristics and/or events that reflect or predict project health. Revealed in a timely manner, these indicators allow for proactive management to influence project outcomes."

The definition reflects several key characteristics of leading indicators such as the leading indicator must not lag but lead, must predict potential risks to future project outcomes, and must be correlated to project outcomes. In the mean time, the question of whether or not the type of statement of a leading indicator should be negative was discussed. From the statement of the research objective, a leading indicator should have a negative impact on project outcomes. In other words, leading indicators might represent a future potential problem that impacts project outcomes. Therefore, it was determined that the statements of leading indicators needed to be phrased negatively. Since the definition of leading indicators states that a relationship exists between leading indicators and project health, the necessity to define project health arose.

4.1.3 Definition of Project Outcomes

The definition of project health is a function of critical success factors. Referred to as project outcomes, the six critical success factors were identified as: 1) cost; 2) schedule; 3) quality/operability; 4) safety; 5) stakeholder satisfaction; and 6) benefit attainment by research members. These six factors are generally and traditionally used to measure project success especially in many industries. Later on, however, benefit attainment was omitted from the list because benefit attainment for the owner can only be assessed after the facility has been operating for a period of time; therefore, measuring this outcome was beyond the scope of the research. The definitions for each project outcome are detailed below as provided by research team members:

- **Cost:** Cost performance is viewed in terms of overall actual final cost verses the established project budget. Secondary cost outcomes can include cost / cash flow deviation (compliance with spending plans), cost efficiency, (how efficiently an asset is design and constructed verses similar facilities in industry), and consumption of contingency or reserves.

- **Schedule:** Schedule performance is viewed in terms of overall actual final duration verses the planned project duration. Secondary schedule performance can include outage duration performances and overall engineering and construction cycle time (for certain fast track projects).
- **Quality / Operability**: Quality and Operability are outcomes that are based upon a facility being capable of operating per its intended function and that the quality of the facility and construction craftsmanship matches the intended asset life. (For example, if we build a facility that is intended to make 100 widgets a day, the facility should be capable of making 100 widgets a day).
- **Safety**: Safety as an outcome is a combination of the construction safety during the course of the project and the overall safety considerations of the new facility that will enable it to operate safely over its production life-cycle. Construction safety involves the accidents to personnel in the battery limits of the construction zone and is general viewed in terms of recordable or Days Away or Restricted Time (DART) cases. Facility safety is of a more long-term outcome and is based upon the facility having the equipment, protections, and or warning/safety devices, safe job procedures, energy control procedures etc. required for the facility to operate in a safe manner.
- **Stakeholder Satisfaction**: Stakeholder satisfaction is the overall pride, satisfaction, contentment and / or happiness that the stakeholders have with the outcome of the project. It is somewhat a measure of the potential for future repeat business.

4.1.4 Screening of Leading Indicators

After identifying leading indicators and project outcomes, a qualification process for each leading indicator was conducted. In this process, a leading indicator was reviewed and checked one by one, determining: 1) whether or not each leading indicator complied with the definition; 2) what potential problem does a leading indicator address; 3) what categories of project health does a leading indicator affect; 4) whether or not there is a tangible measure for a leading indicator; and 5) whether or not the leading indicator is unique to the owner, contractor, or both.

After the review, sixty six leading indicators that were very similar or identical were screened out and newly identified leading indicators were added. Finally, 126 leading indicators (115 leading indicators were left and 11 new leading indicators were added) were set for the first survey. Appendix C shows 126 LIs used in the first survey.

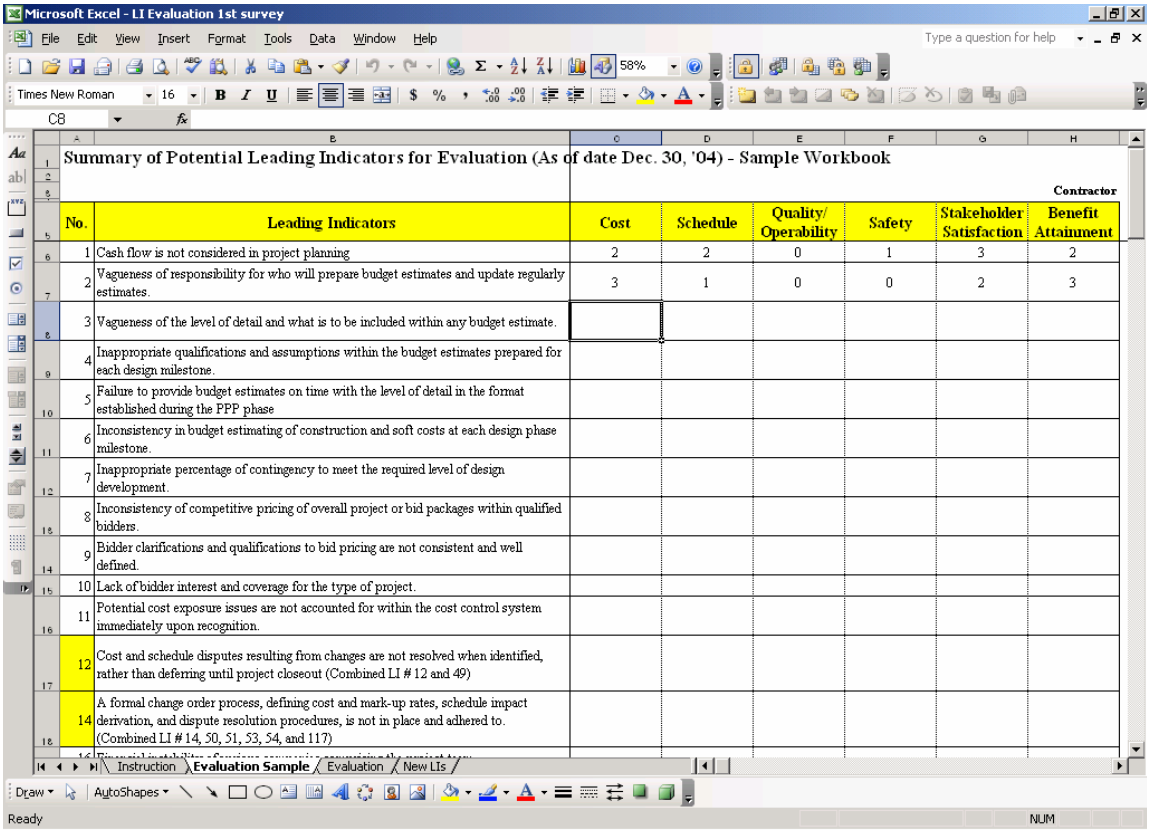
4.2 The First Survey

The purpose of this evaluation survey was to determine which of the 126 LIs had the most significant negative impact on project outcomes, to reduce the number of LIs for the further study, and to compare perspectives between owner, contractor, engineer respondents, and the aggregate response. The research team members were asked to evaluate the impact of leading indicators (LIs) on project outcomes and fifteen members replied. The first survey was performed internally because the survey method needed to be tested before performing a large scale survey later. Due to small sample size for contractors and engineers, these two groups were collapsed into a single contractor group for analysis. The results were summarized by ranking the LIs according to the impact on the aggregate of all project outcomes as well as the impact on individual project outcomes.

4.2.1 Questionnaire

The questionnaire used Microsoft Excel® spreadsheets and was sent via email to research members. The questionnaire consisted of four tabs: Introduction, Evaluation Sample, Evaluation, and New LIs. The introduction tab explained how to fill out the questionnaire. The evaluation sample tab showed input examples. The evaluation tab collected the inputs from survey participants. The new LIs tab provided spaces for suggested LIs from participants.

The concept of measuring LIs is converting negative impacts on outcomes to numbers (point scale) and adding the numbers to determine the magnitude of the negative impact each LI has on project outcomes. In detail, a four-point measurement scale was used. Respondents were instructed to mark 3 if an LI has a high negative impact, mark 2 for a medium impact, mark 1 for low impact and mark 0 for minimal or no impact on project outcomes. Thus, the aggregated score of an LI for an outcome from participants' input indicates how the LI has negative impact on the outcome. A high aggregated score means a high negative impact on that outcome and vice versa. The detailed analysis method is described in the following section. The screen capture of the evaluation sample tab from a spreadsheet is shown in Figure 3.



No.	Leading Indicators	Cost	Schedule	Quality/ Operability	Safety	Stakeholder Satisfaction	Benefit Attainment
1	Cash flow is not considered in project planning	2	2	0	1	3	2
2	Vagueness of responsibility for who will prepare budget estimates and update regularly estimates.	3	1	0	0	2	3
3	Vagueness of the level of detail and what is to be included within any budget estimate.						
4	Inappropriate qualifications and assumptions within the budget estimates prepared for each design milestone.						
5	Failure to provide budget estimates on time with the level of detail in the format established during the PPP phase						
6	Inconsistency in budget estimating of construction and soft costs at each design phase milestone.						
7	Inappropriate percentage of contingency to meet the required level of design development.						
8	Inconsistency of competitive pricing of overall project or bid packages within qualified bidders.						
9	Bidder clarifications and qualifications to bid pricing are not consistent and well defined.						
10	Lack of bidder interest and coverage for the type of project.						
11	Potential cost exposure issues are not accounted for within the cost control system immediately upon recognition.						
12	Cost and schedule disputes resulting from changes are not resolved when identified, rather than deferring until project closeout (Combined LI # 12 and 49)						
14	A formal change order process, defining cost and mark-up rates, schedule impact derivation, and dispute resolution procedures, is not in place and adhered to. (Combined LI # 14, 50, 51, 53, 54, and 117)						

Figure 3. Screen Capture of Evaluation Example Tab First Survey Questionnaire

4.2.2 Data Analysis

Participants for the first survey consisted of three contractors, three engineers, and nine owners, with the contractor and engineer groups combined into one group. As stated above, an individual assessment of a LI for each outcome was performed and a calculation of the negative impact of a LI on each outcome was made. Table 1 shows a partial list of LIs illustrating how the negative impact of each LI on cost outcome was calculated by contractors, owners, and overall. The scores listed under the columns of contractors, owners, and overall mean the amount of negative impact on the cost outcome. The maximum negative score for contractors is 18 (the maximum negative point is 3 and, thus, 3 multiplied by the number of people which is 6), for owners is 27 (3 multiplied by 9), and for overall is 45 likewise.

Table 1. Estimating the Negative Impact of Each LI on Cost Outcome

LI No.	In put from 15 Participants								Estimated Negative Impact on Cost Outcome by Groups		
	Six Contractors			Nine Owners					Contractors (max score: 18)	Owners (max score: 27)	Overall (max score: 45)
	1	· · ·	6	1	2	· · ·	8	9			
1	2	· · ·	3	1	2	· · ·	0	2	15	14	29
2	2	· · ·	2	2	2	· · ·	1	2	12	16	28
3	2	· · ·	2	2	3	· · ·	3	2	13	22	35
4	1	· · ·	2	2	2	· · ·	2	1	14	19	33
5	2	· · ·	1	3	1	· · ·	1	2	13	14	27
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
188	1	· · ·	1	2	1	· · ·	1	1	14	15	29
189	1	· · ·	1	1	1	· · ·	0	1	8	7	15
190	1	· · ·	1	1	0	· · ·	0	1	8	9	17
191	1	· · ·	0	0	0	· · ·	1	1	6	4	10
192	2	· · ·	1	0	1	· · ·	1	0	8	4	12

Next, the negative impacts of each LI on other outcomes were calculated likewise. The overall negative impacts of all outcomes were summed and ranked by the total score. In this table, the scores listed under the column of total means the amount of negative impact on all six outcomes and, thus, the total maximum negative score is 270 (the maximum negative score for an outcome is 45 multiplied by 6 outcomes). Table 2 illustrates how the overall ranking of LIs was determined by adding the scores of outcomes.

Table 2. Overall Ranking of LIs by Total Scores for Each Outcome

LI No.	Cost	Schedule	Quality/ Operability	Safety	Stakeholder Satisfaction	Benefit Attainment	Total (max score: 270)	Ranking
148	36	38	34	27	34	31	200	1
79	36	40	35	22	32	30	195	2
43	40	39	25	19	36	33	192	3
123	37	37	36	17	30	31	188	4
150	34	36	28	23	33	27	181	5
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
135	14	12	11	0	13	9	59	122
183	17	9	5	3	15	6	55	123
182	13	13	10	1	12	5	54	124
192	12	5	10	6	9	10	52	125
142	13	9	6	3	14	6	51	126

Then, the data were summarized by rankings based on overall group response, contractor response, and owner response. Table 3 shows the rankings of LIs by overall, contractor, and owner groups.

Table 3. Ranking of LIs by Overall, Contractors, and Owners

No.	Overall	Contractors	Owners
148	1	13	1
79	2	4	3
43	3	7	2
123	4	2	7
150	5	15	3
⋮	⋮	⋮	⋮
135	122	123	121
183	123	123	122
182	124	105	125
192	125	114	124
142	126	123	123

There were significant variations in the results with respect to each participant and the group. For example, LI 148 in Table 3 is ranked first in owner group but ranked thirteenth in contractor group. This may reflect the fact that the interpretation of LIs might differ based on each participant response and the perceived negative impact of a LI on project outcomes. Thus, an understanding of a LI and the assessment of a LI's impact on project outcomes may be influenced by the nature of project work, the individual performing the assessment, and the company perspective from which the participant answered the questions. Especially, the differences between owners and contractors portrayed in the results were examined in detail in Chapter V using statistical analysis.

After ranking all LIs, a method to reduce the number of LIs was considered. Reducing the number of LIs was important because a tool with a small set of LIs is likely more useful than a tool with a large set of LIs in terms of usability. The method used was that the final number of LIs combined the top 50 LIs based on comparisons between the overall, contractor, and owner responses. This comparison suggests a list of 66 LIs (greater than 50 because some LIs in the top 50 were selected by one group and not the other).

The group also decided that the top 10 LIs from each project outcome category should be included. The review of the top 10 LIs for each project outcome was based on the combined input of all research team members. The rationale behind this approach was that some key LIs might not be included based on the overall results that were highly ranked as having a significant impact on a specific project outcome. For example, there were four LIs related to safety that did not make the top 50 but were highly ranked in terms of the safety outcome (within the top 10). As a result, 13 LIs were added to the revised list. Thus, a total of 79 LIs were retained based on the analysis. Appendix D illustrates all rankings of LIs and how 79 LIs were selected and retained.

4.2.3 Added Leading Indicators

The participants proposed 42 new LIs and these LIs were subsequently evaluated. Many of the new LIs were already on the current list in some form, and were therefore discarded. Because the scope of the research addresses only the project execution phases (detailed design, procurement of materials and equipment, construction, and start up), any LIs thought to be relevant to the pre-project planning phase were not included on the list. However, some LIs may be related to work accomplished during pre-project planning. For example, if the project is authorized with a high PDRI score (say greater than 200), a LI should be included in the list that is related to updating the PDRI score as detailed design is performed. Thus, a new LI was added to cover this situation. Finally, eight new LIs were identified and they are as follows:

- Prefabrication delivery priorities have been defined in bid inquiry documents in support of construction geographic area sequencing.
- Premature field mobilization prior to engineering being ready.
- Are drawings being released as Approved For Construction with excessive "Holds?"
- Well organized project filing system
- HAZOP late or excessive number of outstanding items on HAZOP not complete during design execution.

- Is team encouraged to be realistic and truthful, even if news may be bad - what is the “safe to say” culture?
- Did Project Manager seek out lessons learned on similar, previous projects?
- The project has a high PDRI score which is greater than 200 at authorization.

4.2.4 Rephrasing Leading Indictors

Rephrasing LI statements was performed to enhance the meaning of each LI. The proposed standard format reflects a complete sentence starting with the sentence subject, without using acronyms in the statement. As decided in an earlier section, the LI statements were rephrased in a negative form using complete sentences. Eight LIs were reworded as examples for rephrasing the others. An example of a rephrased LI statement is provided below:

- Before rephrasing: Unproven technology
- After rephrasing: The project uses new technology or construction practices that are unproven in commercial use.

4.2.5 Traditional Measures

There was one issue regarding how traditional measures should be incorporated into the research effort. Traditional measures are being used to quantify project performance. Industry professionals, including both owner and contractor, spend significant time and resources on traditional methods of project control. Although traditional methods are not always effective, these methods have led to improved project outcomes. Thus, rather than simply ignore them, the research team decided to include them and evaluate them along with the leading indicators.

For documentation purposes, the following list of traditional measures and metrics was considered:

- Construction Mgmt / Total Installation Cost
- Total Installation Cost / Process Equipment (Lange Factor)
- Percent Engineering Complete at Start of Construction
- Productivity & Forecasting for Engineering / Construction (CPI, SPI, EAC)
- Source of Estimate (Owner, Contractor, Third party)
- Number Holds on Construction Drawings (Quality of AFC documents)
- Cost Reports (Committed Cost / Spending)
- Milestone Variances
- Cost of Hourly Rate versus Plan (Engineering and Construction)
- Contingency Used (Start of Construction, Reporting Periods)
- Procurement Status (Expediting)
- Submittal Status Report (Vendor Drawings, etc.)
- Over Time Percent
- Accounts Receivable
- Craft Turnover / Availability
- Earned Value = Percent Spend / Percent Budget
- Estimated Quantities versus. Actual Bulks
- Ratio of Engineering / Total Project Cost

- Labor / Material / Equipment versus Total Installation Cost
- Percent Engineering Complete at Authorization
- Type of Estimate (Detailed, Factored, Analogous)
- Mobilization Date
- Team Schedule Development (Wall Schedule, Interactive Planning Session)
- Change Mgmt Planning / Training (Plan)
- Physical Percent Complete versus Percent Plan
- Cash Flow (Spending Actual versus. Plan)
- Number of Change Orders (Pending / Approved)
- Safety Statistics (Drug Test)
- Quality and Turnaround of Requests for Information
- Permitting
- Risk Issues (Major Issues)
- Commissioning Planning
- Quality Control (Factory & Field Testing Results, Percent of Rework)
- Estimated versus Actual Cost (Cost variances)

To identify traditional measures that could be used for this research, the definition of traditional measures was needed and defined by the research team as given below:

> "Traditional measures are the quantifiable metrics indicating past performance of a project by means of budget, time, quality, safety, and risk management processes and tools".

Thus, traditional measures were identified and reviewed to ascertain if any traditional measures fulfilled the leading indicator definition. After reviewing the list of traditional measures, however, it was found that some of the proposed traditional measures were not clear, and thus, dropped from the list. The final list of traditional measures was determined and rewritten in the same form, as the LI statements. Appendix E shows a list of 28 traditional measures with identifiable numbers. Then, the traditional measures were prepared separately for the next survey.

4.2.6 Result

It was acknowledged that the perspectives of owner and contractor groups were different on some LIs. In general, safety had a low correlation with other project health outcomes, regardless of group (e.g., overall, contractor, and owner). Stakeholder satisfaction was highly correlated among the groups. In general, the contractor and owner group responses were highly correlated when including all 126 LIs and the five project outcomes but the correlations between the owner and contractor responses was not as high for the top 50 LIs.

The owner and the contractor group responses identified the same LIs within the top 50; however, the ranking of the top 50 LIs was different and some LIs were included on one group's list but not the other. Thus, the different points of view between owners and contractors needed to be more closely examined in the ensuing surveys. From the analysis of the first survey, the number of LIs was reduced from 126 to 79. Additionally, eight new LIs were added; thus 87 LIs were used in the next survey along with 28 traditional measures. Appendix F shows the list of 87 LIs.

4.3 The Second Survey

The second survey included 87 leading indicators and 28 traditional measures separately. The same format, as used in the first survey, was used for these two questionnaires but with the reduced number of leading indicators and traditional measures added as noted above. The primary purpose of the first and second surveys was to develop a basis for reducing the number of LIs for the final survey. A second purpose of these surveys was to check that the results of the first and the second surveys were consistent. These purposes were achieved as the total number of LIs was reduced and the trend of top ranked LIs from each survey provided similar rankings.

4.3.1 Data Analysis

For the second survey, the research members and representatives from their companies participated. The intent was to increase the sample size and broaden the characteristics of respondents beyond the research team members. Thirty industry professionals (14 contractors and 16 owners) participated in the evaluation of leading indicators and 33 professionals (16 contractors and 17 owners) participated in the evaluation of traditional measures. Some of the participants evaluated both LIs and TMs.

The analysis was accomplished by ranking the LIs and TMs according to the negative impact on overall project outcomes as well as the negative impact on individual project outcomes, identical to the approach used for the first survey. The data were summarized by overall group response, contractor response, and owner response as well. From the results of the second survey, 53 LIs were retained. Appendix G provides all rankings of LIs and how 53 LIs were selected and retained.

The total number of LIs was determined by the method proposed for the analysis of the first survey (combine the top 25 LIs based on comparisons between the overall, contractor, and owner responses, then adding LIs that were not included in the top 25 of the LIs but included in the top 10 for each of the five outcomes). In the second survey, the top 25 LIs were selected as a guideline in screening LIs for the next survey instead of the top 50, which was a guideline in screening LIs for the first survey.

There was constant discussion among research team members about the benefit of reducing the number of LIs for the tool. Research team members strongly believed that a useful tool means a simple tool. Considering the nature of project management professionals, who are usually busy, and thus, do not like tools that are complex, making an easy to use tool was the key in developing the tool. To accomplish this, reducing the number of LIs was indispensable, and therefore, a decision was made to use the top 25 as a guideline instead of the top 50 for further LI reduction.

4.3.2 Combining Leading Indicators and Traditional Measures

During the analysis, it was found that some LIs may have had an incorrect impact on the ranking due to poor wording or similarities among LIs. To correct these matters, seven LIs were reworded and seven LIs were removed from the list. Some LIs and TMs were measuring the same attribute but at different times (all TMs were written in past tense while all LIs were written in present or present progressive tense). To resolve this matter, eliminating TMs from the research scope was considered (originally, incorporating TMs was not in the research scope).

A decision was made that those TMs, with characteristics similar to LIs, should be included in the final LI list. According to this decision, where considered appropriate, 17 TMs: TM 2, 3, 6, 8, 10, 11, 12, 13, 16, 19, 22, 24, 28, 30, 32, 37, and 39, became LI candidates (see Table 4 for descriptions of these LIs). Then a final sorting was performed. After the sorting, three sets of LIs and TMs that were found to be fairly similar to each other. They were LI 7 and TM 6, LI 14 and TM 30, and LI 69 and TM 22. Among them, LI 7, TM 30, and TM 22 were dropped. Later TM 33 was added to the list of LI candidates. Therefore, a total of 16 TMs became new LIs and the verb tense of these TMs was changed into present tense. To identify LIs that originated from TMs, the number 200 was added to the original TM number. For example, TM 2 became LI 202. Table 4 provides all the LIs and TMs discussed above.

Table 4. List of LIs and TMs for Review

No.		Description
Leading Indicators	7	Inappropriate percentage of contingency to meet the required level of design development.
	14	A formal change order process, defining cost and mark-up rates, schedule impact derivation, and dispute resolution procedures, is not in place and adhered to. (Combined LI # 14, 50, 51, 53, 54, and 117)
	69	Engineering Deliverables IFC Deviation from Schedule
Traditional Measures	2	Actual project cash flow reflected a substantial deviation from planned cash flow.
	3	The actual hourly wage rate for direct field construction labor and/or engineering/design staff was much higher than the estimated hourly wage rate.
	6	The dollar contingency used was higher than planned at key reporting milestones (e.g., start of construction).

Table 4. Continued

No.		Description
Traditional Measures	8	The project had a substantial level of outstanding accounts payable or accounts receivable.
	10	Actual bulk material quantities were greater than estimated or forecasted total bulk material quantities (e.g., steel, straight run pipe, electrical wire and cable).
	11	The project team has not consistently used look ahead schedules for short range planning.
	12	Floats for project activities have been used at an increasingly high rate.
	13	The project frequently missed key milestone dates.
	16	The project had a low percent engineering/design completion at the start of construction.
	19	The receipt of actual vendor drawing was later than the planned receipt of vendor drawing.
	22	Actual release of Approved for Construction (AFC) drawings was later than planned release of AFC drawings.
	24	Actual schedule activities were behind planned scheduled activities over several reporting periods.
	28	Forecasts-to-complete based on actual project experience combined with actual expenditures to date have consistently showed overruns in engineering/design, procurement, and/or construction budgets (total project or discipline or by project phase).
	30	Project change management process has not identified potential scope changes in a timely manner for decision-making.
	32	Change orders were not approved within a reasonable time period.
	33	The project had an above normal level of rework hours and costs when compared to target levels of rework included in the total budget.
	37	Project quality control results reflected high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.
	39	Actual safety measures were higher than target safety measures in one or more of the following areas: recordable incident rates; Days Away or Restricted Time (DART); first aid cases; incidents and subcontractor incidents; and safety program compliance, including drug test results.

4.3.3 Result

The survey results revealed marked consistency in establishing the top ranked LIs between the first and the second surveys. By comparison, LIs in both surveys were generally ranked the same. However, the results of both surveys also showed that the contractor's perspective and owner's perspective reflected different points of view. These differences in points of view were understandable for those LIs where major differences in ranking occurred between the two groups. These differences needed to be considered when developing the tool.

After the analysis, 53 LIs were retained but 7 LIs were dropped after further analysis, because some LIs could only be assessed during pre-project planning, which was outside of the scope of the research, and some LIs were similar to other LIs. Thus 46 LIs remained. Later, three new LIs were added. The first one addressed cultural difference between parties. The second one added was about procurement. The third one added was regarding unrealistic goals or requests from the client or upper management. Therefore, the total number of LIs was 65 (46 screened LIs + 16 new LIs from TMs + 3 newly added LIs). Soon after, two LIs (one previously screened out LI and one new LI) were added. For easy identification, numbers from 301 to 304 were assigned for these four new LIs. Finally, 67 LIs were prepared for the third survey. Appendix H shows list of 67 LIs included in the third survey.

4.3.4 Project Practice Group

In the meantime, sorting LIs in another category was considered. The new grouping would be helpful when reviewing the final list of LIs, analyzing the results of the final survey, and building the tool. Specifically, identifying new groups was an attempt to aid the user of the tool to identify where opportunities for improvement exist. The categories can help to identify potential sources of risks to project outcomes and guide the user toward a potential mitigation strategy.

Initially, the following 13 groups were identified: Alignment, Change Management, Constructability, Contracting, Cost Control, Decision Making, Estimating and Cash Flow, Material Management, Planning for Startup, Quality Management, Safety Practice, Schedule Control, And Team Building. All LIs were assigned to one of the defined groups. However, in the third survey, the LIs were presented in random order, rather than as grouped LIs in order to avoid biased answers. These groups were later named "Project Practice Groups" and the characteristics of each group are explained in Chapter VI.

4.4 The Third Survey

The third survey was prepared right after analyzing the second survey. Unlike the previous two surveys, the third questionnaire was sent to all CII member companies (more than 90 organizations including companies and government agencies). During the previous two surveys, participants were fully informed about the intent of the survey before they participated but the third survey participants were too large in number to inform them of the intent of the survey in advance. Therefore, exactly what to ask or measure (capturing the perceptions of impact of each LI on project performance) was carefully integrated into the questionnaire protocol.

4.4.1 Questionnaire

Because the third survey was the last and the largest scale survey among the three surveys, all means for encouraging people to participate in the survey were entertained. The rating scale of the survey was considered first. The decision was choosing between the use of either a six point scale or an eleven point scale. The six point scale was chosen because an eleven point scale might increase the complexity and would probably add time to completing the survey. Thus, a six point scale was used with the following response options: no, very low, low, moderate, high, and very high negative impact on project outcome.

During the design of the Excel spreadsheet as a base format for the questionnaire, it was determined that the user interface needed improvement to help respondents spend less time evaluating leading indicators. In addition, the questionnaire should minimize the use of worksheets to avoid complexity. Other information, such as characteristics of the respondent's company (owner, contractor, or engineer), the company name, and the participant's name, was collected. However, the questionnaire sought to minimize this type of information to reduce the time burden for respondents. This research did not attempt to control any variables other than owner versus contractor.

4.4.2 Qualification of Participants

To increase the data quality, the survey needed to be completed by respondents with a certain level of project experience. The following job classifications were suggested: Operation Manager, Project Manager, Senior Project Manager, Engineering Manager, Construction Manager, Superintendent, Or Project Control Manager. The survey instructions requested that a company return up to five surveys completed by respondents in any of the job classifications listed above.

4.4.3 Survey Method

Various survey methods were considered, including emailing a survey package, uploading a survey package on a website, mailing a survey package (traditional way), and using survey software. Because the previous survey method (using Microsoft Excel spreadsheets and sending via e-mail) was successful and the results were satisfactory, the same method was chosen. A three-week survey period was considered sufficient and the questionnaires were sent on June 16, 2005. July 8, 2005 was set for the due date. After two weeks passed, an email reminder of the due date was sent.

4.4.4 Pretest

A pretest was performed to measure the total time to complete the survey and check any potential problems using a draft questionnaire. People from both owner and contractor groups participated in the pretest. The pretest result showed no notable problems but certain comments were valuable. One comment was to make the survey printable so that people could fill it out and return via fax or mail. After the pretest, the final questionnaire was created. Figure 4 illustrates a screen capture of the input tab of the questionnaire.

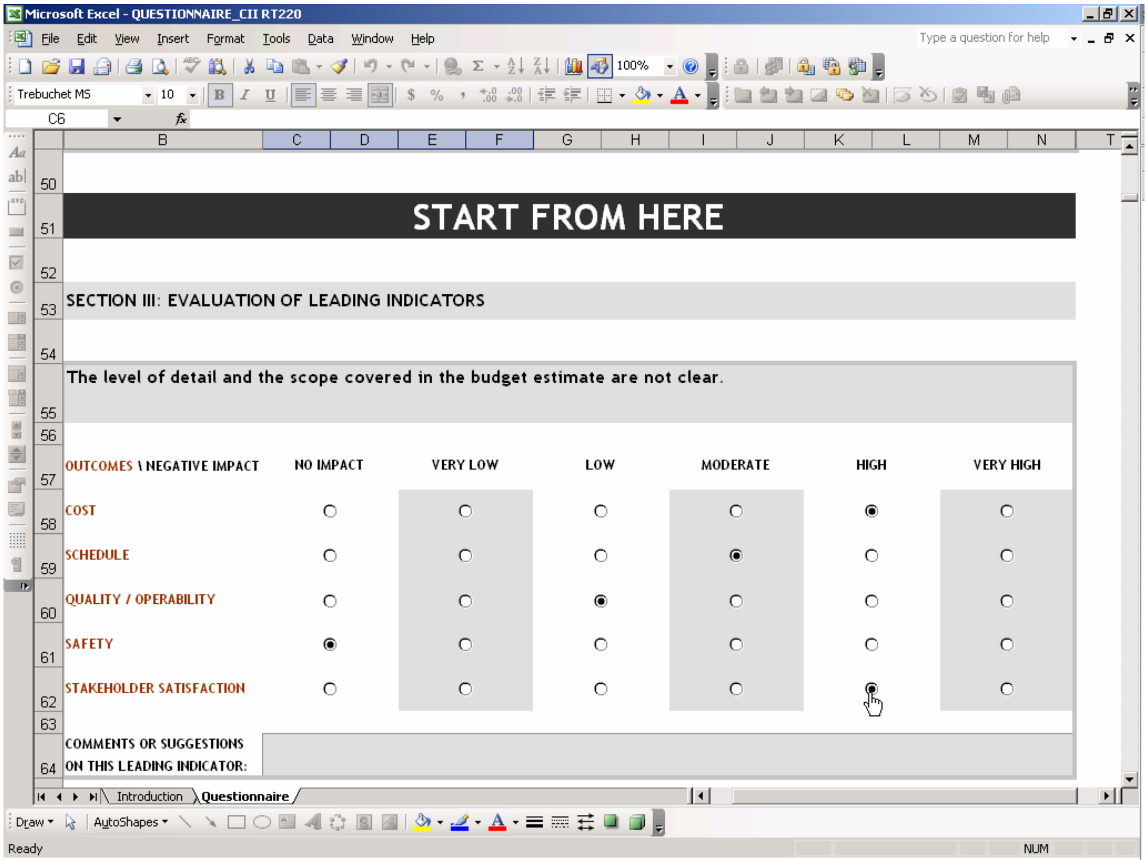


Figure 4. A Screen Capture of the Input Tab for the Third Survey Questionnaire

Appendix I shows the entire protocol used for the third survey.

4.4.5 Comments from Participants

Although this survey was the last survey, survey participants were allowed to add LIs, in case there were any missed leading indicators on the list. From the comments of previous participants, vague terms and ambiguous sentences in the LIs were fixed. Overall comments for the research and newly suggested LIs from respondents were reviewed. There were no noticeable comments concerning the research and no additional

LIs were found. All suggested LIs from this survey were already covered by existing LIs or eliminated based on earlier low rankings.

4.4.6 Result

A total of 84 respondents completed the final survey: 26 owners and 58 contractor/engineer/designer respondents. These respondents represented 32 companies: 14 owner companies and 18 contractor/engineer/designer companies. Although the 84 responses were less than expected, the number posed no problem for statistical analysis. Finally, 49 LIs were identified out of the 67 LIs by the 25+10 method (combining the top 25 LIs based on comparisons between the contractor/engineer/designer and owner response, and adding LIs that were not in the top 25 but were in the top 10 for each of the five outcomes). Appendix J illustrates all rankings of LIs and how 49 LIs were selected and retained. These 49 LIs were set to be the base LIs for determining the final LIs.

Seven LIs from the 49 LIs were deleted after thorough examination of each LI because they were covered by other LIs or confirmed as lagging indicators (12, 69, 81, 103, 184, 213, and 239). Therefore, the number of LIs was refined to 42. Later, LI 186 was added to the list and eventually, the number of LIs was finalized to 43. The input scores for each LI were analyzed for the new tool in the next chapter. Table 5 provides the list of LIs mentioned above and their descriptions.

Table 5. List of LIs for Review

LI No.	Leading Indicators
12	Cost and schedule disputes resulting from changes are not resolved when identified and resolution is deferred until project closeout.
69	Engineering/design deliverables are not completed on time as planned per the project schedule.
81	The project lacks a clearly defined plan that identifies who has input on quality issues, collects information and/or has the final decision on issues under dispute.
103	The project is experiencing a high frequency of near misses.
184	Team competencies and other issues impacting performance are not being addressed as they are identified.
186	The project is experiencing difficulties in integrating schedules between participants.
213	The project frequently missed key milestone dates.
239	Actual safety measures were higher than target safety measures in one or more of the following areas: recordable incident rates; Days Away or Restricted Time (DART); first aid cases; incidents and subcontractor incidents; and safety program compliance, including drug test results.

4.5 Order of Leading Indicators

The order of 43 LIs needed to be arranged. Originally, they were listed in ascending order of original LI numbers. After that, LI 148, 150, and 67 were switched to the LI 3, 14, and 16 because LI 148, 150, and 67 have relatively high negative impact on each outcome. Then LI 3, 14, and 16 were placed where LI 148, 150, and 67 had been. New LI numbers from 1 to 43 were assigned to the LIs in the order as stated above. Table 6 shows the list of 43 final LIs with new and old (original) numbers.

Table 6. Forty Three Leading Indicators

New No.	Old No.	Leading Indicators
1	148	The project team is lacking in the necessary expertise, experience, breadth, and depth to successfully execute the project.
2	150	The project team is experiencing a high turnover rate and instability in team membership.
3	67	The project team's response to Requests for Information, questions, and changing events that can significantly impact the project results is slow, inadequate, or incomplete.
4	33	The project team is losing confidence in the accuracy and validity of the schedule.
5	38	Project milestones are not being met and are consequently jeopardizing future project milestones.
6	39	Construction is awarded before adequate completion of project design, including discipline design packages, resulting in an incomplete scope definition at time of award/start of construction.
7	40	Business goals, project objectives and priorities, and critical success factors are not being consistently used by project team members and key stakeholders to guide decisions.
8	43	Owner and/or contractor are requesting an excessive number of contract changes and/or scope changes during project execution (detailed design, procurement, construction, and start up).
9	59	Significant project scope items are inadvertently omitted from bid packages.
10	16	Some project participant companies become financially unstable.
11	79	The project is experiencing a high level of engineering/design/specification errors and scope changes.
12	83	A project specific quality plan is not consistent with the contract documents (plans and specifications).
13	85	The project fails to follow the quality plan for construction in relation to the roles and requirements of those who are responsible for that plan.
14	91	The project is experiencing a high level of safety incidents.
15	92	Design reviews fail to include qualified personnel who can analyze safety ergonomics, and/or loss prevention features of plans and specifications.

Table 6. Continued

New No.	Old No.	Leading Indicators
16	93	The project team personnel lack involvement in safety inspections, awareness of safety issues, and education in safety practices.
17	94	Potential safety related problems are not being resolved in a timely manner.
18	95	The project is experiencing an increasing level of worker non compliance in safety practices.
19	101	The project is not following the requirements of a project specific safety plan during construction.
20	104	Owner and contractor project personnel are not properly aligned.
21	110	The project lacks sufficient skilled craft and is experiencing high craft turnover due to competition from other projects, low wages, and/or undesirable work schedules.
22	112	The project lacks sufficient staff, bulk materials, small tools, and construction equipment to adequately support planned construction activities.
23	122	The level of maintenance and reliability personnel involvement in detailed design is low and the personnel lack alignment with other project team personnel with respect to maintenance issues for the facility.
24	123	The project is using new technology or construction practices that are unproven in commercial or industrial use.
25	139	The project team is failing to identify and/or address missing requirements during detail design reviews.
26	3	The level of detail and the scope covered in the funding authorization estimate are not per estimating guidelines.
27	149	The project manager (or team leader) is lacking in the required level of experience and skills.
28	14	Project changes are not being processed in a timely manner for decision making (includes defining cost and mark-up rates, evaluating schedule impact, obtaining appropriate approval authority, and initiating dispute resolution procedures).
29	152	Key project stakeholder(s) is (are) exhibiting poor relationships and pursuing private agenda.
30	168	Commitments are increasingly made with the intention of not being met and are almost always not met.

Table 6. Continued

New No.	Old No.	Leading Indicators
31	186	The project is experiencing difficulties in integrating schedules between project participants.
32	187	The project is frequently asking vendors, suppliers, service providers, and contractors to perform functions outside their areas of expertise and experience.
33	197	Process Hazard Analysis (PHA) is late and/or is experiencing an excessive number of operational/support items that are not complete during the design phase.
34	198	The project team is not being realistic and truthful when project circumstances are unfavorable.
35	210	Actual installed bulk material quantities are greater than estimated or forecasted total bulk material quantities (e.g., steel, concrete, straight run pipe, electrical wire and cable).
36	212	Float for project activities is being used up at an increasingly high rate.
37	224	Actual schedule activities are lagging behind planned scheduled activities over several reporting periods.
38	228	Forecasts-to-complete based on actual project experience, actual commitments, and actual expenditures are projecting overruns.
39	233	The project is experiencing an above normal level of construction rework hours and costs when compared to target levels of rework included in the total budget or schedule.
40	237	Project quality control results are reflecting high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.
41	301	The project is experiencing difficulties due to the lack of understanding cultural differences.
42	302	Material and/or equipment prices are increasing rapidly for certain types of materials/equipment that represent a high percent of the project cost.
43	303	The client and/or upper management is frequently making unreasonable requests (includes setting unrealistic goals).

Hereafter, the LI numbers used in the rest of the paper are the new LI numbers.

CHAPTER V

TOOL DEVELOPMENT

The detail development procedure of the tool is explained in this chapter. Weighted scores calculated from the final survey are used to measure project health. Specifically, calculating weighted scores, tool concept, establishing LI measurement criteria, tool design, tool testing, tool modification, tool validation, analysis of validation result, and finalizing the tool are described in the following sections.

5.1 Survey Analysis

After finalizing the leading indicators for the tool, eighty four evaluators' perception were quantified and used to develop the tool. A detail method used to measure the negative impact of the 43 LIs on project outcomes is explained. Then, initial weights were obtained from the survey result and added to the calculated negative impacts of each LI for project outcomes. Finally, the issue of separating survey analyses by owner and contractor groups was discussed and resolved.

5.1.1 Changing Perception to Numbers

As described in the previous chapter, each participant provided input for each of five outcomes for leading indicators. Therefore, there are 215 inputs (43 LIs multiplied by 5) per participant and 18,060 total inputs (215 multiplied by 84 participants) were received from the final survey. A six-point scale was used for the questionnaire and the answers were converted into points as shown in Table 7.

Table 7. A Six-point Scale Used for the Questionnaire

Scale	No	Very low	Low	Moderate	High	Very high
Point	0	1	2	3	4	5

Therefore, the total negative impact of an LI for an outcome could be measured by adding the points from all participants. For example, calculating the negative impact of LI 1 on the cost outcome is shown in Table 8.

Table 8. Calculating the Negative Impact of LI 1 on Cost Outcome

LI No.	Outcome	Points converted from answers from 84 participants							Total score
		1	2	3	· · ·	82	83	84	
1	Cost	5	5	5	· · ·	5	5	4	396
	Schedule	5	5	5	· · ·	5	5	4	370
	Quality	4	5	4	· · ·	5	5	4	339
	Safety	5	5	4	· · ·	5	5	3	319
	Satisfaction	4	5	4	· · ·	5	5	3	361
2	Cost	4	3	4	· · ·	5	3	4	313
	Schedule	4	4	4	· · ·	5	4	3	327
	Quality	4	4	4	· · ·	4	4	4	297
	Safety	4	3	4	· · ·	5	3	2	256
	Satisfaction	4	4	4	· · ·	5	2	2	318
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 8. Continued

LI No.	Outcome	Points converted from answers from 84 participants							Total score
		1	2	3	· · ·	82	83	84	
43	Cost	4	5	3	· · ·	4	4	2	318
	Schedule	4	5	4	· · ·	4	4	2	328
	Quality	4	5	3	· · ·	4	4	1	254
	Safety	5	4	3	· · ·	3	4	1	243
	Satisfaction	5	5	3	· · ·	4	4	3	329

Thus, the aggregated score of 396 is the estimated amount of negative impact of LI 1 on cost outcome. An identical calculation was made for the other outcomes. The results were a score of 370 for schedule, 339 for quality, 319 for Safety, 361 for satisfaction. In this manner, all 215 negative impacts of 43 LIs on each outcome were recorded.

5.1.2 Weighting

The estimated negative impacts were to be used for the tool, but because the questionnaire format just used a six point scale, the negative impact difference between LIs was not large enough to use for the tool. Thus, applying different weights for LIs was necessary. To assign a weight for each LI, the standard deviation of the questionnaire answers from 84 participants was used. The standard deviations of the questionnaire answers ranged from around 0.5 to 1.2. This indicated that, for some LIs with a small standard deviation, participants provided consistent answers.

However, for some LIs that had large standard deviation, participants provided inconsistent answers. In other words, if two LIs had the same amount of negative impact on a certain outcome, one LI that had small standard deviation had more impact than the other LI that had a large standard deviation. Therefore, the weight was determined by dividing the aggregated score of a LI by the standard deviation of the aggregated score for that LI based on survey answers. Table 9 shows the weighted scores of LI 1, 2, and 43 per outcome (see Appendix K for weighted scores for all LIs per outcome).

Table 9. The Weighted Scores of LI 1, 2, and 43 per Outcome

LI No.	Outcome	Points from answers by 84 participants							Total score	S.D*	Weighted Score**
		1	2	3	· · ·	82	83	84			
1	Cost	5	5	5	· · ·	5	5	4	396	0.62	594
	Schedule	5	5	5	· · ·	5	5	4	370	0.58	634
	Quality	4	5	4	· · ·	5	5	4	339	0.80	425
	Safety	5	5	4	· · ·	5	5	3	319	1.07	297
	Satisfaction	4	5	4	· · ·	5	5	3	361	0.72	498
2	Cost	4	3	4	· · ·	5	3	4	313	0.83	379
	Schedule	4	4	4	· · ·	5	4	3	327	0.84	391
	Quality	4	4	4	· · ·	4	4	4	297	0.87	341
	Safety	4	3	4	· · ·	5	3	2	256	1.13	227
	Satisfaction	4	4	4	· · ·	5	2	2	318	0.96	332
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 9. Continued

LI No.	Outcome	Points from answers by 84 participants							Total score	S.D*	Weighted Score**
		1	2	3	· · ·	82	83	84			
43	Cost	4	5	3	· · ·	4	4	2	318	0.98	324
	Schedule	4	5	4	· · ·	4	4	2	328	1.00	328
	Quality	4	5	3	· · ·	4	4	1	254	1.26	201
	Safety	5	4	3	· · ·	3	4	1	243	1.28	190
	Satisfaction	5	5	3	· · ·	4	4	3	329	1.09	302

* S.D: Standard deviation, ** Total score divided by standard deviation

Thus, 43 weighted scores were developed for the tool.

5.1.3 Owner versus Contractor

The different perception between owner and contractor was discussed earlier in Chapter IV. At this point, this issue must be resolved to proceed further either for developing one tool for both owner and contractor, or developing two tools for each owner and contractor. In other words, the survey analysis can be performed either using the aggregated results from all participant input (i.e. combining owner and contractors) or can be performed using aggregated results by owner and contractor separately.

Owners and contractors have different perspective regarding certain LIs and, therefore, the negative impacts obtained on outcomes of the LIs between the two parties varied. To identify exactly what LIs reflect different perspectives of the owner and contractor, statistical analyses were used. A F-test and a T-test with 95% confidence interval were performed. To test the variance between owner and contractor, a F-test was carried out in advance. Table 10 shows the test result for safety outcome. In the table, the probabilities of LI 30 and 35 are less than 0.05 (5%) and this explains that the averages of the owner and contractor of these LIs are statistically different.

Table 10. The F-test and T-test Result for Safety Outcome

LI No.	26 Owners			58 Contractors			Owner	Contractor	F-Test 95% C.L.	T-Test 95% C.L.
	1	· · ·	26	1	· · ·	58	Ave.	Ave.		
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
29	3	· · ·	4	0	· · ·	1	2.31	2.69	0.613	0.247
30	5	· · ·	3	1	· · ·	2	2.19	2.84	0.747	0.040
31	3	· · ·	3	0	· · ·	2	2.19	2.38	0.466	0.499
32	4	· · ·	4	2	· · ·	3	3.27	3.16	0.503	0.694
33	5	· · ·	5	0	· · ·	3	3.46	3.48	0.572	0.947
34	4	· · ·	3	1	· · ·	1	2.88	3.09	0.800	0.505
35	2	· · ·	0	1	· · ·	1	1.12	1.81	0.447	0.005
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

The T-test results disclosed that 27 LIs showed a statistically significant difference between owner and contractor groups with respect to the perceived negative impact on a project outcome. Specifically, for the cost outcome, LI 16, 18, 19, 20, 22, 27, and 40 were different; for the schedule outcome, LI 26 and 43 were different; for the quality outcome, LI 19, 25, and 26 were different; for the safety outcome, LI 7, 8, 13, 30, 35, 36, 37, 40, and 42 were different; and for the satisfaction outcome, LI 3, 8, 11, 28, 35, 36, and 40 were different. Table 11 provides a description of LIs that were different.

Table 11. List of LIs Where Negative Impacts on Outcomes Differ Between Owner and Contractor Groups

New No.	Leading Indicators
3	The project team's response to Requests for Information, questions, and changing events that can significantly impact the project results is slow, inadequate, or incomplete.
7	Business goals, project objectives and priorities, and critical success factors are not being consistently used by project team members and key stakeholders to guide decisions.
8	Owner and/or contractor are requesting an excessive number of contract changes and/or scope changes during project execution (detailed design, procurement, construction, and start up).
11	The project is experiencing a high level of engineering/design/specification errors and scope changes.
13	The project fails to follow the quality plan for construction in relation to the roles and requirements of those who are responsible for that plan.
16	The project team personnel lack involvement in safety inspections, awareness of safety issues, and education in safety practices.
18	The project is experiencing an increasing level of worker non compliance in safety practices.
19	The project is not following the requirements of a project specific safety plan during construction.
20	Owner and contractor project personnel are not properly aligned.
22	The project lacks sufficient staff, bulk materials, small tools, and construction equipment to adequately support planned construction activities.
25	The project team is failing to identify and/or address missing requirements during detail design reviews.
26	The level of detail and the scope covered in the funding authorization estimate are not per estimating guidelines.
27	The project manager (or team leader) is lacking in the required level of experience and skills.
28	Project changes are not being processed in a timely manner for decision making (includes defining cost and mark-up rates, evaluating schedule impact, obtaining appropriate approval authority, and initiating dispute resolution procedures).

Table 11. Continued

New No.	Leading Indicators
30	Commitments are increasingly made with the intention of not being met and are almost always not met.
35	Actual installed bulk material quantities are greater than estimated or forecasted total bulk material quantities (e.g., steel, concrete, straight run pipe, electrical wire and cable).
36	Float for project activities is being used up at an increasingly high rate.
37	Actual schedule activities are lagging behind planned scheduled activities over several reporting periods.
40	Project quality control results are reflecting high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.
42	Material and/or equipment prices are increasing rapidly for certain types of materials/equipment that represent a high percent of the project cost.
43	The client and/or upper management is frequently making unreasonable requests (includes setting unrealistic goals).

From the result, owners and contractors hold more divergent opinions about cost, safety, and satisfaction than schedule and quality. In general, however, the number of LIs that owners and contractors perceive differently is 12.5% (27 out of 215); it was decided that this difference did not constitute enough reason to analyze the two groups separately. Thus, the aggregating scores and weightings were performed without separating the groups.

5.2 Tool Concept and Development Criteria

As noted in the methodology section, the prototype of the new tool was based on the PDRI tool. Using the new tool, if a project manager wanted to check the health of a project at any point in time during project execution, he/she could evaluate 43 LIs to determine what health score was generated.

For example, if there are negative indications, such as discord among team members during execution of a project, the project outcomes will potentially be at risk of not being met. Thus, the concept is that if there is no indication of problems based on assessing leading indicators when evaluating a project using the new tool, the tool output score of the project should be high. If there are problems then the output should be lower depending on the severity of the problems.

Early in the development phase of the tool, criteria were brainstormed by the research team members to guide tool development. The key criteria were:

1. Easy to use
2. Results easy to understand
3. Basis of periodic reviews
4. Prepared independent of the project team
5. Fast to fill out
6. Powerful enough to alter the outcome of the project
7. Real time tool
8. Gap analysis and strategy to reduce the gap
9. Appropriate number of questions
10. Split by project phases
11. Sustainable tool - expandable tool (add questions/ratings, etc.)

Most of the criterion became a basis for developing the tool with the exception of criterion 10 and 11. These two criteria could not be incorporated into the tool because of a conflict with intent of the tool. Later in this chapter, how these two criteria were handled with respect to the tool development is explained. During a review of the criteria, the characteristics of the tool were identified more specifically. Based on these concepts and criteria, the tool structure was developed.

5.3 Developing the Definition of each Leading Indicator

After the weighted scores for outcomes of each LI were identified, devising an evaluation method for each LI was needed. Taking an approach similar to the evaluation of elements in the PDCS tool was found to be most effective. To help users in evaluating LIs and using the tool, a detail definition and evaluation criteria of each LI were described in a clearly stated format.

5.3.1 Format for Definition of Leading Indicator

A specific format was developed to provide users with detailed information concerning each LI. The contents were LI number and name, measurement considerations, definition, source documents and references.

To assess Leading Indicators, a five-point scale was proposed. This scale reflects the severity of the problem as serious, major, moderate, minor, and no problem. If a project has a problem for a certain Leading Indicator, the evaluator will assess the Leading Indicator using a negative focus. An example of the five-point scale termed measurement considerations for Leading Indicator 1 is shown below:

Leading Indicator 1 - The project team is lacking in the necessary expertise, experience, breadth, and depth to successfully execute the project.

1. Serious Problem - The project team has several weak or inexperienced members, and the gaps are not being addressed.
2. Major Problem - The project team has at least one weak or inexperienced member, whose lack of competency is not being addressed.
3. Moderate Problem - The project team has had to replace and/or augment one or more members after several months of low performance, due to lack of competency or lack of experience.
4. Minor Problem - The project team assesses its gaps (and generally has few gaps), but only moves to mitigate the problems if pushed by the owner or contractor.
5. No Problem - The project team is experienced and competent. As such, it regularly assesses its gaps (if any) and proactively moves to strengthen the team.

The measurement considerations for each LI were developed in the same manner. The measurement considerations give users a baseline for assessing LIs. Further, providing a description of each LI, along with measurement considerations, helps users fully understand the LIs. Source documents are materials within a company that may contain information about the LI, and which may help users decide the correct scale when assessing an LI. Finally, references are materials potentially related to the LI found in CII publications, so that users can review those materials referenced that may help mitigate problems indicated by the leading indicators. As an example, the complete definition of LI 1 is shown in Table 12.

Table 12. An Example of Definition for LI 1

<table>
<tr><td colspan="2">Leading Indicator 1
The project team is lacking in the necessary expertise, experience, breadth, and depth to successfully execute the project.</td></tr>
<tr><td colspan="2">Measurement Considerations
1 The Project Team has several weak or inexperienced members, and the gaps are not being addressed.
2 The Project Team has at least one weak or inexperienced member, whose lack of competency is not being addressed.
3 The Project Team has had to replace and/or augment one or more members after several months of low performance, due to lack of competency or lack of experience.
4 The Project Team assesses its gaps (and generally has few gaps), but only moves to mitigate the problems if pushed by the owner or contractor.
5 The Project Team is experienced and competent. As such, it regularly assesses its gaps (if any) and proactively moves to strengthen the team.</td></tr>
<tr><td colspan="2">Description
In addition to the Project Managers (see the Leading Indicator on Project Managers), the quality of the entire project team is an important factor in determining project success. The core project team typically consists of Project Engineers, Discipline Engineers (Process, Civil, Mechanical, Electrical, Piping, and Control Systems), Procurement Specialists, and Project Services (estimating, scheduling, cost control).
If the core project team (either the Owner’s or the Engineering Contractor’s) is weak and inexperienced, the project is not likely to be a success. The Project Manager needs to be able to recognize key deficiencies on the team, and proactively make changes before the project health is endangered. Replacing key individuals or bringing on additional resources are the typical responses to gaps identified in the course of a project.</td></tr>
<tr><td>Source Documents
• Organization Charts
• Team Resumes</td><td>References
• RS134-1 Identifying Success Factors for High Performance Project Teams
• RS37-1 Team Building: Improving Project Performance
• IR111-3 Core Competency Toolkit</td></tr>
</table>

Appendix L shows all definitions for 43 LIs.

5.4 Regrouping Project Practice Groups

As noted earlier, the grouping of 65 LIs into 13 categories was completed after the second survey. After analyzing the third survey, each practice group needed to be reviewed because the total number of LIs was reduced to 43 after the final survey and several initial practice groups were merged with each other. In detail, planning for startup and a LI related to decision making were included in alignment; a LI related to decision making was included in change management; schedule control, estimating and cash flow, material management, and cost control were included in the new practice group, project control. Therefore, eight practice groups were identified: alignment, change management, constructability, contracting, quality management, safety practice, project control, and team building.

5.4.1 Definition of each Project Practice Group

A project practice is a process or method that, when executed effectively, leads to enhanced project performance. Six practices identified in this study are the same as Best Practice categories of the CII. The other two project practices were identified from CII knowledge areas and they are commonly considered important for achieving project success. The eight project practices are described below:

- **Alignment:** These are practices associated with the overall alignment of the project team with respect to project goals and objectives. The make-up of project teams can change considerably from the Pre-Project Planning Phase to the Execution Phase. The owner project team generally changes from business planning personnel to those responsible for implementation. New contractors and suppliers are also usually added at this time. Both owner and contractor teams are generally expanded to address the increasing volume of work. How these new team members and contractors understand and are aligned to common goals plays a key role to project success.

- **Change Management:** CII and others have accumulated large amounts of research regarding the effects of late project scope changes and high volumes of rework to poor project outcomes. How the project team makes decisions on, controls, tracks, and implements change on a project can have a significant effect on project outcomes.
- **Constructability:** Constructability generally involves construction related methodology and planning. The ability to efficiently plan and execute the construction of a facility is a major driver behind project success.
- **Contracting**: Contracting in terms of a practice is based on the matching of contract types to project risks. It is not an endorsement of any one particular contract type. There is no weighting of the tool that values Turnkey versus Lump Sum versus Design-Build versus Cost Reimbursable. It is purely a measure of whether the project team is seeing potential issues between the contracts in place and the scope that needs to be executed.
- **Quality Management**: Quality Management includes items such as quality of engineering, construction quality and rework, equipment inspections and testing, and facility start-up.

- **Safety Practices**: This is a measure of whether or not the project team is fully engaged in the practices that drive project safety (see CII Target Zero practices).
- **Project Control:** Project controls involves the tools and techniques used to track, evaluate and improve schedule and cost performance. In terms of this tool, it is not simply the use of a project schedule and cost reporting. It is a measure of how accurate the schedule is; how effective the schedule is in tracking work and identifying gaps; whether the cost reporting is utilized in future decision making; and whether or not the team is effectively using the information as a planning tool. Too often, schedules and cost reports become deliverables themselves instead of tools to be used in planning the work.
- **Team Building:** People implement projects. The core competencies of the people that constitute the project team and how the people that make-up the project team play a very key role in the success of any project. Good project teams overcome gaps in scope, risk events, design issues, project changes etc., in a proactive way to minimize the negative effects on project outcomes. Poor teams do not.

Appendix M identifies which LIs are assigned to each of the eight project practices.

5.5 Tool Design

As described in the previous chapter, the concept behind the tool is changing an evaluator’s perceptions of current project status into a health score based on an embedded weight assigned to each LI. Using this weight, the specific method used to generate health scores is explained in the following sections.

5.5.1 Normalization of Weighted Scores

The weighted scores from Table 9 were to be used for the tool but the scores were normalized because it was hard to understand the exact negative impact with the raw numbers. Similar to PDRI, the weighted scores were normalized to a total of 1000. For example, the sum of the weighted scores for the cost outcome of 43 LIs was 18176. 1000 divided by 18176 generated a normalization factor of 0.055018. By multiplying the normalization factor by each weighted score, a normalized score for the cost outcome of each LI was obtained. The normalization factors for other outcomes should be different from each other. Table 13 shows the procedure for calculating normalized scores.

Table 13. The Procedure for Calculating Normalized Scores

LI No.	Weighted Score for Cost Outcome	Calculating Normalization Factor	Normalizing each Score	Normalized Score
1	594	1000 ÷ 18176 = 0.055018	594 × 0.055018 = 33	33
2	379		379 × 0.055018 = 21	21
⋮	⋮		⋮	⋮
43	324		324 × 0.055018 = 18	18
Total	18176		18176 × 0.055018 = 1000	1000

The health score range for the new tool used the same range as PDRI score (0 to 1000). Although a low PDRI score represents a better-defined project scope definition package just prior to detailed design, a low health score of the new tool represents a high potential risk of not meeting a performance target in the future. In other words, 0 is the best score for PDRI but the worst score for the new tool. If all 43 Leading Indicators indicate that a project is experiencing no problems, then the overall score is 1000, the maximum score. If the Leading Indicators reflect a variety of problems from minor to serious, the maximum score reduces. The extent of the reduction reflects the potential negative impact the different Leading Indicators have on the five project outcomes.

5.5.2 Generating Outcome Health Scores

As noted earlier, aggregated scores of each LI for outcomes became the basis of calculating the impact of LIs on outcomes. The initial weights (hereafter referred to as the normal weight) for the LIs in the tool were derived by dividing the aggregated score of a LI by the standard deviation of the survey answers for that LI. Then, the weighted scores were normalized to be used in the tool.

These normalized scores (see Table 13) determined the scores for the rating of “serious problem” assigned to the LIs. Thereafter, a linear relationship for the problem scale in the tool was assumed. In other words, the model simply assigned each of the six point scale, a multiplier of serious (maximum points) = 100%, major = 75%, moderate = 50%, minor = 25%, and none = 0% to the normalized scores to quantify the risk impact of the LI. Table 14 shows an example of how a health score is calculated for the cost outcome.

If a user thinks LI 1 is a major problem for a project then 25 points (see Table 14) is subtracted from 1000 points for the cost outcome health score for the project, and when the other LIs are evaluated, the health score is calculated likewise. After the user assesses all 43 Leading Indicators and the sum of the scores from each LI for a particular outcome is 274, the Health Score would be 726 for the cost outcome (1000 minus 274).

Table 14. Health Score Calculation for Cost Outcome

LI No.	Normalized Score for Cost Outcome	Measurement of Leading Indicators					Selected Score by User
		Serious	Major	Moderate	Minor	None	
		100% of weighted score	75% of weighted score	50% of weighted score	25% of weighted score	0% of weighted score	
1	33	33	25	16	8	0	25
2	21	21	16	15	8	0	8
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
43	18	18	13	9	4	0	9
Total	1000	1000	750	500	250	0	274
Health Score	Health score for cost outcome is 726 (1000 – 274)						726

This concept is applied to generating the project practice scores as well.

5.5.3 Generating Practice Health Scores

Although the concept of obtaining the practice health scores is the same as outcome health scores, the method of generating practice health scores varies from that of the outcome health scores. Because a practice group consists of several LIs, there is no need to consider outcome scores. Only a score for an LI is needed and the score is obtained by aggregating all outcome scores for the LI. Once the normalized scores for LIs of a practice group are calculated, the rest of the process to generating the health score for the practice group is almost the same as generating an outcome health score.

As an example, the process of obtaining a health score for the contracting practice group that consists of three LIs (see LI 6, 9, and 10 in Table 6) is described below. First of all, aggregate all outcome scores for each LI and then calculate normalized scores. Table 15 shows the process of generating normalized scores for this contracting practice group.

Table 15. Process of Generating Normalized Scores for Contracting Practice Group

<table>
<tr><th>LI No.</th><th>Outcome</th><th>Weighted Score for Outcome</th><th>Aggregated Score for LI</th><th>Calculating Normalization Factor</th><th>Normalizing each Score</th><th>Normalized Score</th></tr>
<tr><td rowspan="5">6</td><td>Cost</td><td>531</td><td rowspan="5">1621</td><td rowspan="5">1000÷5008 =0.199681</td><td rowspan="5">1621×0.199681= 324</td><td rowspan="5">324</td></tr>
<tr><td>Schedule</td><td>389</td></tr>
<tr><td>Quality</td><td>235</td></tr>
<tr><td>Safety</td><td>183</td></tr>
<tr><td>Satisfaction</td><td>283</td></tr>
</table>

Table 15. Continued

LI No.	Outcome	Weighted Score for Outcome	Aggregated Score for LI	Calculating Normalization Factor	Normalizing each Score	Normalized Score
9	Cost	706	2008	1000÷5008 =0.199681	2008×0.199681= 401	401
	Schedule	613				
	Quality	227				
	Safety	141				
	Satisfaction	321				
10	Cost	324	1379		1379×0.199681= 275	275
	Schedule	359				
	Quality	211				
	Safety	174				
	Satisfaction	311				
Total			5008		5008×0.199681= 1000	1000

The next procedure is the same as that of generating outcome scores. A linear relationship was assumed as well for the problem levels in the tool. Therefore, the model assigned a multiplier of serious (maximum points) = 100%, major = 75%, moderate = 50%, minor = 25%, and none = 0% of the normalized scores to quantify the risk impact of the LI. Table 16 shows an example of generating a contracting practice health score when a user thinks LI 6 is a minor problem, LI 9 is moderate, and LI 10 is no problem for a project. The total of 281 points is subtracted from 1000 points for the contracting practice health score and thus the health score is 719 for the contracting practice group (1000 minus 281).

Table 16. Generating Contracting Practice Health Score

LI No.	Normalized Score for Cost Outcome	Measurement of Leading Indicators					Selected Score by User
		Serious	Major	Moderate	Minor	None	
		100% of weighted score	75% of weighted score	50% of weighted score	25% of weighted score	0% of weighted score	
6	324	324	243	162	81	0	81
9	401	401	300	200	100	0	200
10	275	275	207	138	69	0	0
Total	1000	1000	750	500	250	0	281
Health Score	Health score for contracting practice group is 719 (1000 – 281)						719

5.5.4 Displaying Output

How to illustrate the output in an easy to understand format was one of the major considerations in developing the tool. The PDRI tool simply displays a score itself. It may be because the PDRI tool has only one index to present. The prospective tool, however, has twelve indexes to present (one overall, five outcomes, and eight project practices). Therefore, an approach to simplify the whole picture of a project's health was necessary. As introduced in the literature review, the alignment thermometer was a good example of how to help users understand team alignment status quickly and correctly with graphics.

Various methods such as graphs and thermometer type graphics were considered for the new tool. Finally, gauges resembling a speedometer on a dashboard were adopted. However, designing the gauges using an Excel spreadsheet was another problem. Fortunately, a book that provided many tips to make speedometer-like gauges was found and the method was applied (Hawley and Hawley 2004). Each gauge has three color ranges: red, yellow, and green. The initial default ranges were set one third for red, one third for yellow, and one third for green for all outcomes and project practices. Figure 5 shows the gauge used for the tool.

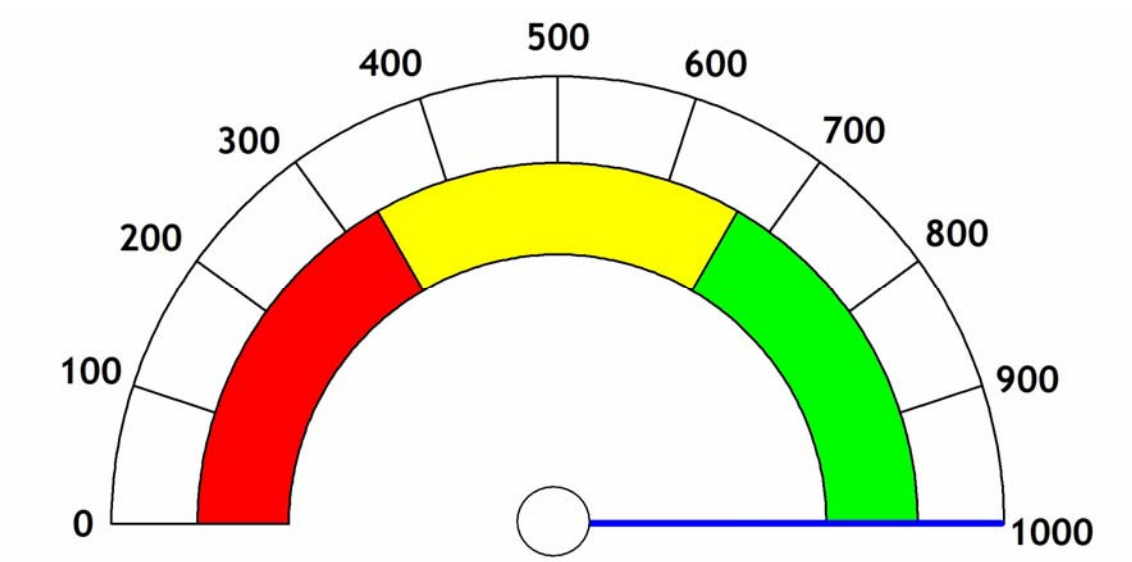


Figure 5. Gauge Used for the Tool

The color ranges were used for the gauge as a simple indication of project health. Green is considered low risk; yellow is considered moderate risk; red is considered high risk. However, not all organizations view risks equally. Also, individual projects may have different business drivers that allow for certain risks on specific outcomes. Therefore, the color ranges were designed to be customized so that users could change each range according to their needs.

5.5.5 Tool Structure

The basic structure of the tool was composed of inputs and outputs. The input part contains all 43 LIs to be evaluated. The output part shows the results using the gauges for outcome and practice health scores. Additionally, an information component for using the tool and a customization module were added.

5.5.6 Tuning up

There was a consideration about separating the tool by two project phases: engineering-design-procurement and construction because some LIs could only be assessed either in the engineering-design-procurement or in the construction phase. Thus, each LI was reviewed to determine whether or not the LI was applicable to engineering-design-procurement, construction, or both phases. A proposed method to resolve this issue was to exclude the score for the LI from calculation of health score, if the LI was "not applicable" to a particular project phase. By doing this, the requirement for having two tools, one for the engineering-design-procurement phase and another one for the construction phase, was deemed unnecessary.

5.6 Tool Test

The first test of the draft tool was performed with research team members prior to the final tool testing. Two sets of testing protocols (one for completed projects and another one for current projects) were developed to guide this testing process. The testers were asked to select two completed projects and two current projects: one successful and one unsuccessful project for each case and to evaluate the projects using the draft tool that was provided. Research team members were also asked to answer a questionnaire. The questions asked about the use of the tool and specific performance data relevant to the target projects, such as planned and actual project cost and duration, along with suggestions for the tool's improvement. Appendix N provides the two testing protocols for the tool test.

5.7 Test Result

During this first test of the tool, problems in using the tool were minimal, but an issue arose regarding the cumulative affect of the LI weighting on the different outcomes. Two effects were observed. First, the risk scoring for the five outcomes tended to be very similar. Since LIs that have high impact were included in the tool, the range in the LI weights across all outcomes was not extensive. This caused some concern since the results did not always highlight the outcomes that may be at a higher risk of poorer performance.

Second, it was noted that the normal weighting (dividing by a standard deviation) often did not create substantial differences between outcomes. Thus, alternate weighting methods were explored that would produce differences in the risk assessments. Said another way, dividing by the standard deviation might not be sufficient enough to differentiate between outcome scores. Based on these two issues, it was concluded that a new method to test different scoring weights was needed.

5.8 Modifying Tool

To solve the aforementioned issue, a higher weighted option was used that tends to emphasize the LIs that have consistent answers (small standard deviations) from the survey and de-emphasize the LIs that have inconsistent answers (large standard deviations). To generate different weights, adjusting the standard deviation using different powers was considered. Because the standard deviation was used as a divisor in generating weighted scores, increasing the power of the standard deviation increases the weight of an LI exponentially if the standard deviation is smaller than 1.0 and decreases the weight of an LI if the standard deviation is greater than 1.0 (see Table 9).

However, what power is appropriate was still in doubt. Thus, it was decided to generate different weighted scores using five different powers of the standard deviation and choose one of the powers according to the tool validation test results. Specifically, five different powers, without power, third power, fifth power, seventh power, and ninth power of standard deviation, were selected and used. Table 17 shows an example of how the five different weighted scores were generated for the cost outcome.

Table 17. Generating Five Different Weighted Scores for Cost Outcome

LI No.	Total Score *	Normal Weight (W1)		Third Power Weight (W3)		Fifth Power Weight (W5)		Seventh Power Weight (W7)		Ninth Power Weight (W9)	
		S.D	Weighted Score	$S.D^3$	Weighted Score	$S.D^5$	Weighted Score	$S.D^7$	Weighted Score	$S.D^9$	Weighted Score
1	369	0.62	594	0.24	1539	0.09	3987	0.04	10329	0.01	26762
2	313	0.83	379	0.56	554	0.39	811	0.26	1188	0.18	1739
3	343	0.85	402	0.62	552	0.45	759	0.33	1042	0.24	1432
4	317	0.81	390	0.54	592	0.35	899	0.23	1364	0.15	2070
5	339	0.67	508	0.30	1144	0.13	2574	0.06	5790	0.03	13026
6	368	0.69	531	0.33	1108	0.16	2310	0.08	4816	0.04	10041
7	328	0.79	417	0.49	676	0.30	1095	0.18	1774	0.11	2874
8	377	0.80	472	0.51	739	0.33	1158	0.21	1813	0.13	2840
9	384	0.54	706	0.16	2384	0.05	8053	0.01	27202	0.00	91885
10	320	0.99	324	0.96	332	0.94	341	0.92	349	0.89	358
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

* Total Score is the sum of the points input by 84 participants at the third survey.

Hereafter, normal weight was called weight one (W1), the third power weight was called weight three (W3), the fifth power weight was called weight five (W5), the seventh power was called weight seven (W7), and the ninth power weight was called weight nine (W9).

Normalizing the weighted scores using the same method used in Section 6.4.1 was performed. Figure 6 illustrates the normalized weight scores of 10 LIs for the cost outcome by different weight options.

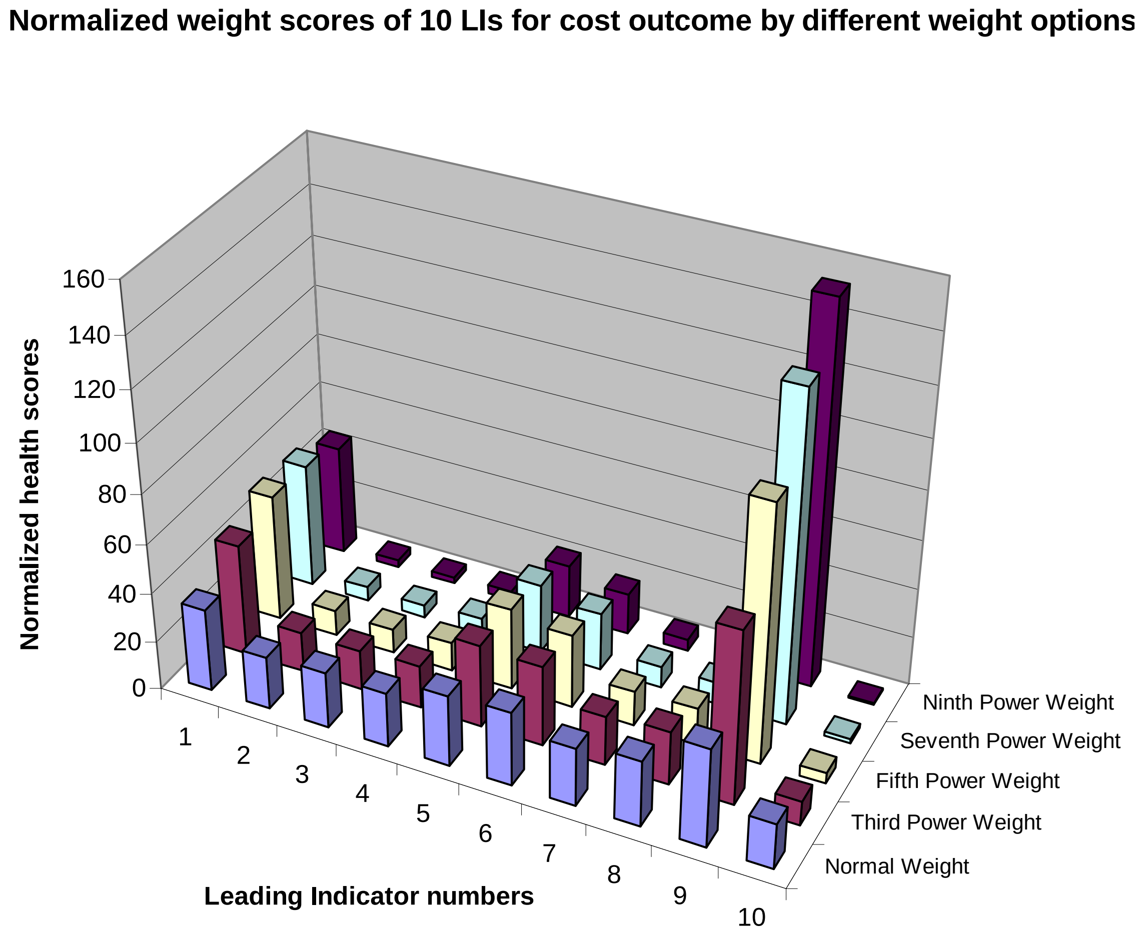


Figure 6. Normalized Weight Scores of 10 LIs for Cost Outcome by Different Weight Options

Appendix O shows normalized weight scores of 43 LIs for five outcomes per each weight option.

Finally, these five different normalized weight scores were embedded in the tool and five buttons were added in the output tabs so that users could change weight as they wanted and see the change of health scores according to the weight change at the same time.

5.9 Tool Validation

Tool validation was performed with CII member companies. The main objectives of the tool validation were to check whether or not the research hypothesis is accepted and to decide which weight is appropriate for the tool. The modified tool was sent with a revised testing protocol to these companies.

5.9.1 Evaluation Method

The basis of the evaluation method was to find a correlation between the tool outputs of a project and the actual performance data of the project. There are four steps for the tool evaluation process: 1) selecting projects to be evaluated; 2) understanding Leading Indicator definitions; 3) evaluating projects using the tool; and 4) completing the evaluation questionnaires. Suggested steps are described below:

1) Participants needed to select two projects and one project should be recently completed. This project should be evaluated in hindsight to help the researcher perform statistical tests to determine validity of the tool. The second project should be a current project authorized for design and construction (front end planning process successfully completed). This project should be in the detailed design phase and/or less than 50 percent complete with construction. The current

project was required for a real time evaluation of the tool, as the tool was intended to be used in practice.

2) Evaluators needed to read the definition of each Leading Indicator until each was understood.

3) For current projects, there were several ways to use the tool: by one evaluator, by more than one evaluator in a group setting, by more than one evaluator with separate evaluations and then aggregating the results. Suggested points in time for project evaluation were when 40 to 60 percent of detailed design was completed and/or when 40 to 60 percent of construction was completed, or select the project phase and percent complete. For completed projects, only one evaluator was needed. Once the decision was made on who and how the evaluation would be performed, it was suggested to open the tool and read the given instructions carefully. The evaluator needed to read each Leading Indicator and select the appropriate response based on the measurement criteria (comment box in the tool or in the Leading Indicator Definition file). Saving the tool as an identifiable name (e.g. combination of project ID, evaluator ID, and the point of time) was strongly recommended. Evaluator(s) should review results – dial gauges for project health parameters and by CII Project Practice Groups. The evaluator(s) should assess whether the dial gauges were showing realistic results relative to the overall actual known performance of the project.

4) Evaluators needed to complete the appropriate evaluation questionnaire concerning the project and results. As it was the one of the objectives of the tool

validation test, evaluators needed to provide the answer regarding which weighting option on the tool output tabs that best described the project health because gathering input on weights through this evaluation was a valuable reference when deciding the proper weight for the tool.

Appendix P shows the memorandum and questionnaires used for the tool validation test.

5.9.2 Required Data

As noted above, the evaluators were asked to select two projects: one completed and one current project and to evaluate the projects using the modified tool. Evaluators were also asked to answer a questionnaire for each project. The questions were asking about the use of the tool and specific performance data of the target projects, along with suggestions for the tool's improvement. Specifically, three different sets of data were required. First, planned cost for a project and actual cost spent for the project were requested. Secondly, planned start date and finish date, and actual start date and finish date were requested. Finally, recorded DART (Days Away, Restricted, or Transferred cases), recorded Recordable Cases, and total direct field craft work hours were requested. Along with the performance data, health scores from each project were needed. Evaluators were allowed to generate five different sets of health scores for project outcomes and project practices by selecting the provided options in the tool for different weighting.

5.9.2 Validation Projects

Fifteen companies participated in the tool validation test including research team members' companies. Unfortunately, fewer companies participated than expected, probably because some questions in the questionnaire were asking confidential information about the projects that they have completed or are currently underway. An important point was that the companies participating in the tool validation represented various industries such as petroleum, pharmaceutical, chemical, energy, and manufacturing. This was advantageous to have reliable result by aggregating inputs from overall industries.

A total of thirty six projects (16 completed and 20 current projects) were assessed for the tool validation. Among them, seven projects (2 completed and 5 current projects) were excluded from the analysis because the project performance information was not provided or not clear enough to be analyzed. Therefore, twenty nine projects (14 completed and 15 current projects) were analyzed.

5.10 Analysis and Results

As noted above, performance data and health scores from each project were obtained. Most evaluators provided cost and schedule performance data but the safety and work hour data was mostly incomplete, because safety related data are often treated as confidential. Therefore, finding correlations between safety performance data and safety health score was not possible. Further, after the thorough review of cost and schedule performance data for both completed and current projects, it was decided that the current project data could not be used due to apparent inconsistencies in the data.

Many evaluators were confused about providing performance data for current projects. Actual cost and completion date for a project that was progressing were not available unless the project was in the late stage of construction. In this regard, the research team desired that evaluators would provide credible data regarding forecasted cost and schedule outcomes. In most cases, the forecasted cost and schedule data lack consistency. Thus, the final analysis was performed using data from fourteen completed projects only. For confidentiality, alphabet letter from A to N was assigned to each project for identification.

5.10.1 Correlation Test

Data analysis was begun with the cost performance data of each project. To be compared with cost outcome health scores, a ratio of actual cost divided by budget cost was calculated. Table 18 shows cost performance ratios and cost health scores with different weights for each project.

Table 18. Cost Performance Ratios and Cost Health Scores with Different Weights

Project	Cost		Ratio (%)	Cost Health Score				
	Baseline	Actual		W1	W3	W5	W7	W9
A	15,545,000	18,707,000	120.34	596	610	613	608	599
B	1,900,000	1,790,000	94.21	965	960	961	965	971
C	8,248,000	8,600,000	104.27	747	724	698	672	650
D	21,023,000	19,500,000	92.76	954	959	968	977	985

Table 18. Continued

Project	Cost		Ratio (%)	Cost Health Score				
	Baseline	Actual		W1	W3	W5	W7	W9
E	173,600,000	177,000,000	101.96	824	817	811	806	804
F	1,900,000	1,921,946	101.16	936	928	925	925	927
G	11,500,000	12,100,000	105.22	935	906	875	846	823
H	9,800,000	10,020,000	102.24	703	722	748	774	794
I	31,797,813	36,382,577	114.42	599	559	527	503	486
J	109,402,277	110,123,086	100.66	801	777	760	750	747
K	129,251,053	138,290,354	106.99	639	635	633	635	638
L	73,000,000	93,000,000	127.40	586	567	558	557	563
M	350,000,000	405,000,000	115.71	741	730	720	710	701
N	103,000,000	102,000,000	99.03	831	808	795	792	797

Next, the schedule performance data were compared with schedule outcome health scores. Calculating a ratio of actual duration divided by planned duration was performed. Actual duration was counted from actual start date to actual finish date. Planned duration was counted from planned start date to planned finish date. The schedule performance data for Project E were not provided and thus thirteen projects were analyzed. Table 19 shows schedule performance ratios and schedule health scores with different weights for each project.

Table 19. Schedule Performance Ratios and Schedule Health Scores with Different Weights

Project	Schedule				Ratio (%)	Schedule Health Score				
	Baseline		Actual			W1	W3	W5	W7	W9
A	5/9/2002	4/9/2004	5/9/2002	4/13/2004	100.57	596	610	613	608	599
B	11/19/2004	1/12/2006	11/19/2004	12/20/2005	94.51	965	960	961	965	971
C	2/14/2005	3/17/2006	2/14/2005	2/19/2006	93.43	747	724	698	672	650
D	2/1/2003	6/18/2004	4/15/2003	6/18/2004	85.49	954	959	968	977	985
F	10/2/2003	6/15/2005	10/28/2003	5/31/2005	93.41	936	928	925	925	927
G	4/1/2004	3/30/2006	4/1/2004	4/30/2006	104.26	935	906	875	846	823
H	12/20/2002	2/20/2004	12/20/2002	3/20/2004	106.79	703	722	748	774	794
I	8/22/2002	8/7/2005	8/22/2002	11/7/2005	108.51	599	559	527	503	486
J	10/2/2002	3/17/2005	10/2/2002	3/17/2005	100.00	801	777	760	750	747
K	1/2/2001	2/5/2003	1/19/2001	8/12/2003	122.38	639	635	633	635	638
L	10/1/1999	10/1/2003	10/1/1999	3/1/2006	160.37	586	567	558	557	563
M	7/1/2003	5/25/2005	7/1/2003	5/25/2005	100.00	741	730	720	710	701
N	1/19/2004	11/30/2005	1/19/2004	12/7/2005	101.03	831	808	795	792	797

After figuring out performance ratios of cost and schedule, the correlation between the ratios and each weighted scores was tested. To test the correlation between them, Microsoft Excel spreadsheet was used. Table 20 and 21 shows the correlation between cost and schedule performance and cost and schedule outcome health scores.

Table 20. Correlation Between Cost Performance and Cost Outcome Health Scores

Project	Ratio (%)	Cost Health Score				
		W1	W3	W5	W7	W9
A	120.34	596	610	613	608	599
B	94.21	965	960	961	965	971
C	104.27	747	724	698	672	650
D	92.76	954	959	968	977	985
E	101.96	824	817	811	806	804
F	101.16	936	928	925	925	927
G	105.22	935	906	875	846	823
H	102.24	703	722	748	774	794
I	114.42	599	559	527	503	486
J	100.66	801	777	760	750	747
K	106.99	639	635	633	635	638
L	127.40	586	567	558	557	563
M	115.71	741	730	720	710	701
N	99.03	831	808	795	792	797
Correlation coefficient		-0.81	-0.82	-0.825	-0.826	-0.823

Table 21. Correlation Between Schedule Performance and Schedule Outcome Health Scores

Project	Ratio (%)	Schedule Health Score				
		W1	W3	W5	W7	W9
A	100.57	596	610	613	608	599
B	94.51	965	960	961	965	971
C	93.43	747	724	698	672	650
D	85.49	954	959	968	977	985
E	-	-	-	-	-	-
F	93.41	936	928	925	925	927
G	104.26	935	906	875	846	823
H	106.79	703	722	748	774	794
I	108.51	599	559	527	503	486
J	100.00	801	777	760	750	747
K	122.38	639	635	633	635	638
L	160.37	586	567	558	557	563
M	100.00	741	730	720	710	701
N	101.03	831	808	795	792	797
Correlation coefficient		-0.647	-0.716	-0.773	-0.812	-0.833

The ratios and the health scores for both cost and schedule were negatively correlated as seen in the table. Although the seventh power weight scores had the highest correlation to ratios, the other correlation coefficients were almost the same for cost outcome. On the other hand, the correlation coefficients for schedule outcome were different from each other.

The normal weight score had the smallest correlation coefficient and the correlation coefficient increased gradually as the power went up. As mentioned above, one of the objectives for the validation test was to select an appropriate weight for the tool. The correlation result was believed to help selecting the weight for the tool. After the review of the result, it was decided that the test was not strong enough to give confidence to decide an appropriate weight for the tool and another method was necessary.

5.10.2 Customized Weight Selection Method

A new method was developed to select an appropriate weight for the tool. The basic concept of the method was that an unsuccessful project must have low health scores and vice versa. In other words, if a tool represented actual project outcome well, the tool received high points but if not, the tool received zero points. The procedure was: 1) grouping fourteen projects into three categories: good, acceptable, bad projects, was performed; to do that, grouping criteria should be defined in advance; 2) generated selection point per weight option for a project according to the assigned category and health score of the project; 3) added selection points per weight option and compare each selection point from each weight option and the weight option that had the highest selection point was likely determined as an appropriate weight for the tool.

First, the fourteen projects were grouped into three categories good, acceptable, and bad projects. Good projects were defined as projects that finished within the planned cost or schedule duration. In other words, projects that had the performance ratio for cost or schedule less than or equal to 100 percent were grouped under good projects. Acceptable projects were defined as projects finished slightly over the planned cost or schedule duration.

In other words, projects that had the performance ratio for cost or schedule over 100 percent but less than or equal to 110 percent were grouped under acceptable projects. Bad projects were defined as projects that exceeded substantially more than the planned cost or schedule duration. In other words, projects that had a performance ratio for cost or schedule over 110 percent were grouped under bad projects. Table 22 illustrates how fourteen projects were grouped into each category.

Table 22. Grouping Fourteen Projects

Cost			Schedule		
Project	Ratio (%)	Group	Project	Ratio (%)	Group
D	92.76	Good	D	85.49	Good
B	94.21	Good	F	93.41	Good
N	99.03	Good	C	93.43	Good
J	100.66	Acceptable	B	94.51	Good

Table 22. Continued

Cost			Schedule		
Project	Ratio (%)	Project	Ratio (%)	Project	Ratio (%)
F	101.16	Acceptable	J	100.00	Good
E	101.96	Acceptable	M	100.00	Good
H	102.24	Acceptable	A	100.57	Acceptable
C	104.27	Acceptable	N	101.03	Acceptable
G	105.22	Acceptable	G	104.26	Acceptable
K	106.99	Acceptable	H	106.79	Acceptable
I	114.42	Bad	I	108.51	Acceptable
M	115.71	Bad	K	122.38	Bad
A	120.34	Bad	L	160.37	Bad
L	127.40	Bad			

Next, selection points were generated. The selection points were given to each weighting option per project from 0 to 5 points according to the awarding criteria. To generate selection points, each project should be categorized in one group. For example, if a project is grouped in the good project group, the project health scores are supposed to be high. Thus, among the five weighted health scores for the project, the highest health score receives five points; the second highest health score receives four points, and the lowest health score receives one point.

On the other hand, if a project is grouped in the bad project group, the project health scores are supposed to be low. Thus, among the five weighted health scores for the project, the lowest health score receives five points; the second lowest health score receives four points, and the highest health score receives one point. For projects that are grouped in the acceptable project group, however, the point awarding criteria are different from others but the concept is the same.

For instance, if a project is grouped in the acceptable project group, the project health scores are supposed to be medium. Thus, among the five weighted health scores for the project, the medium health score receives five points; the health score that has the smallest difference to the medium health score receives four points, and the health score that has the largest difference to the medium health score receives one point. These were the awarding criteria and additionally, if the difference between the largest health score and the smallest health score of a project is less than or equal 30, then no selection point (zero) is given to all five weighted options regardless of the awarding criteria.

In other words, the difference among weighted numbers is less than three percent is considered that there is no difference among weight options. Table 23 shows how the selection points for cost outcome were awarded according to the criteria.

Table 23. Awarding Selection Points for Cost Outcome According to the Criteria

Project	Ratio (%)	Cost Health Score					Selection Point				
		W1	W3	W5	W7	W9	W1	W3	W5	W7	W9
D	92.76	954	959	968	977	985	1	2	3	4	5

Table 23. Continued

Project	Ratio (%)	Cost Health Score					Selection Point				
		W1	W3	W1	W3	W1	W3	W1	W3	W1	W3
B	94.21	965	960	961	965	971	0	0	0	0	0
N	99.03	831	808	795	792	797	5	4	2	1	3
J	100.66	801	777	760	750	747	1	2	5	4	3
F	101.16	936	928	925	925	927	0	0	0	0	0
E	101.96	824	817	811	806	804	0	0	0	0	0
H	102.24	703	722	748	774	794	2	3	5	3	1
C	104.27	747	724	698	672	650	1	3	5	3	2
G	105.22	935	906	875	846	823	1	3	5	4	2
K	106.99	639	635	633	635	638	0	0	0	0	0
I	114.42	599	559	527	503	486	1	2	3	4	5
M	115.71	741	730	720	710	701	1	2	3	4	5
A	120.34	596	610	613	608	599	0	0	0	0	0
L	127.40	586	567	558	557	563	0	0	0	0	0
Total Selection Points							13	21	31	27	26

Table 24 shows how the selection points for schedule outcome were awarded according to the criteria.

Table 24. Awarding Selection Points for Schedule Outcome According to the Criteria

Project	Ratio (%)	Schedule Health Score					Selection Point				
		W1	W3	W5	W7	W9	W1	W3	W5	W7	W9
D	85.49	944	931	915	899	883	5	4	3	2	1
F	93.41	943	947	956	966	975	1	2	3	4	5
C	93.43	768	789	817	847	875	1	2	3	4	5
B	94.51	962	955	950	949	951	0	0	0	0	0
J	100.00	793	760	731	707	690	5	4	3	2	1
M	100.00	737	729	726	727	731	0	0	0	0	0
A	100.57	592	609	628	647	664	1	3	5	3	1
N	101.03	837	816	794	772	750	2	3	5	3	1
G	104.26	949	945	943	942	944	0	0	0	0	0
H	106.79	665	630	597	567	540	1	3	5	4	2
I	108.51	617	605	606	615	628	0	0	0	0	0
K	122.38	629	612	598	587	579	1	2	3	4	5
L	160.37	562	497	427	359	299	1	2	3	4	5
Total Selection Points							18	25	33	30	26

Finally, the total selection points from each of the cost and schedule outcomes were added for final decision of the weight for the tool as shown in Table 25.

Table 25. Total Selection Points by Adding Points from Cost and Schedule Outcomes

Weight options	W1	W3	W5	W7	W9
Total Selection Points from Cost Outcome	13	21	31	27	26
Total Selection Points from Schedule Outcome	18	25	33	30	26
Total	31	46	64	57	52

Weight option five has the largest selection point, and therefore, selected for appropriate weight for the tool.

5.10.3 Results

In conclusion, dividing the total score by the fifth power of the standard deviation produced a higher (not the highest) correlation and represented actual project outcomes well from the customized weight selection test. Therefore dividing the total score by the fifth power of the standard deviation was chosen as the scoring method of choice for the tool; it was designated the amplified weight. Table 26 and 27 shows the difference between normal and amplified weight. As seen in the table, if the standard deviation is low, the amplified score increases the impact exponentially and vice-versa.

Table 26. Normalized Scores for Normal Weight

LI No.	Total Score *	Normal Weight						
		S.D	Weighted Score	Normalized Score				
				Serious	Major	Moderate	Minor	None
1	369	0.62	594	33	25	16	8	0
2	313	0.83	379	21	16	10	5	0
3	343	0.85	402	22	17	11	6	0
4	317	0.81	390	21	16	11	5	0
5	339	0.67	508	28	21	14	7	0
6	368	0.69	531	29	22	15	7	0
7	328	0.79	417	23	17	11	6	0
8	377	0.80	472	26	19	13	6	0
9	384	0.54	706	39	29	19	10	0
10	320	0.99	324	18	13	9	4	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 27. Normalized Scores for Amplified Weight

LI No.	Total Score *	Amplified Weight						
		S.D[5]	Weighted Score	Normalized Score				
				Serious	Major	Moderate	Minor	None
1	369	0.09	3987	49	37	25	12	0
2	313	0.39	811	10	7	5	2	0
3	343	0.45	759	9	7	5	2	0
4	317	0.35	899	11	8	6	3	0
5	339	0.13	2574	32	24	16	8	0
6	368	0.16	2310	28	21	14	7	0
7	328	0.30	1095	13	10	7	3	0
8	377	0.33	1158	14	11	7	4	0
9	384	0.05	8053	99	74	50	25	0
10	320	0.94	341	4	3	2	1	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

However, there was one drawback in using the amplified weight (fifth power of the standard deviation). This method diminishes the impact of a certain LIs with large standard deviations, regardless of the total score of the LI from the survey. Figures 7 and 8 illustrate the weight score changes of 10 LIs for cost outcome by normal and amplified weights.

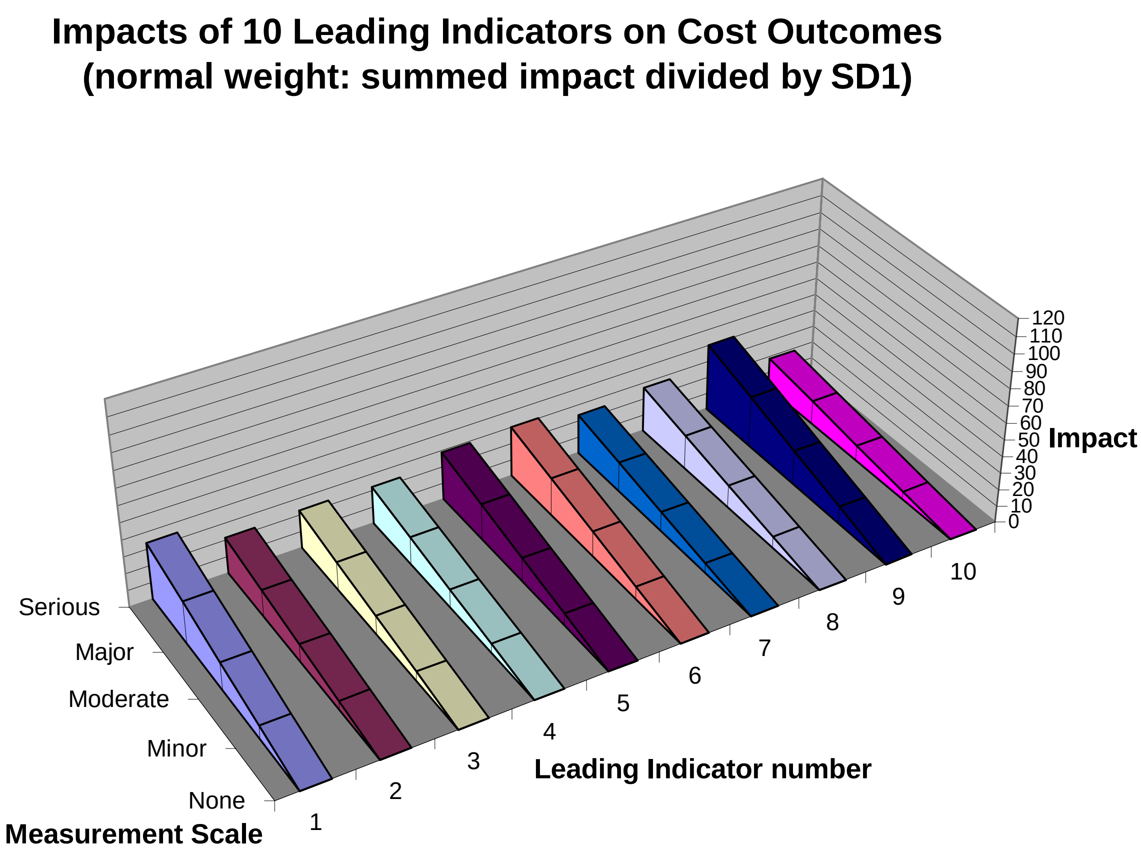


Figure 7. Weight Score Changes of 10 LIs for Cost Outcome by Normal Weights

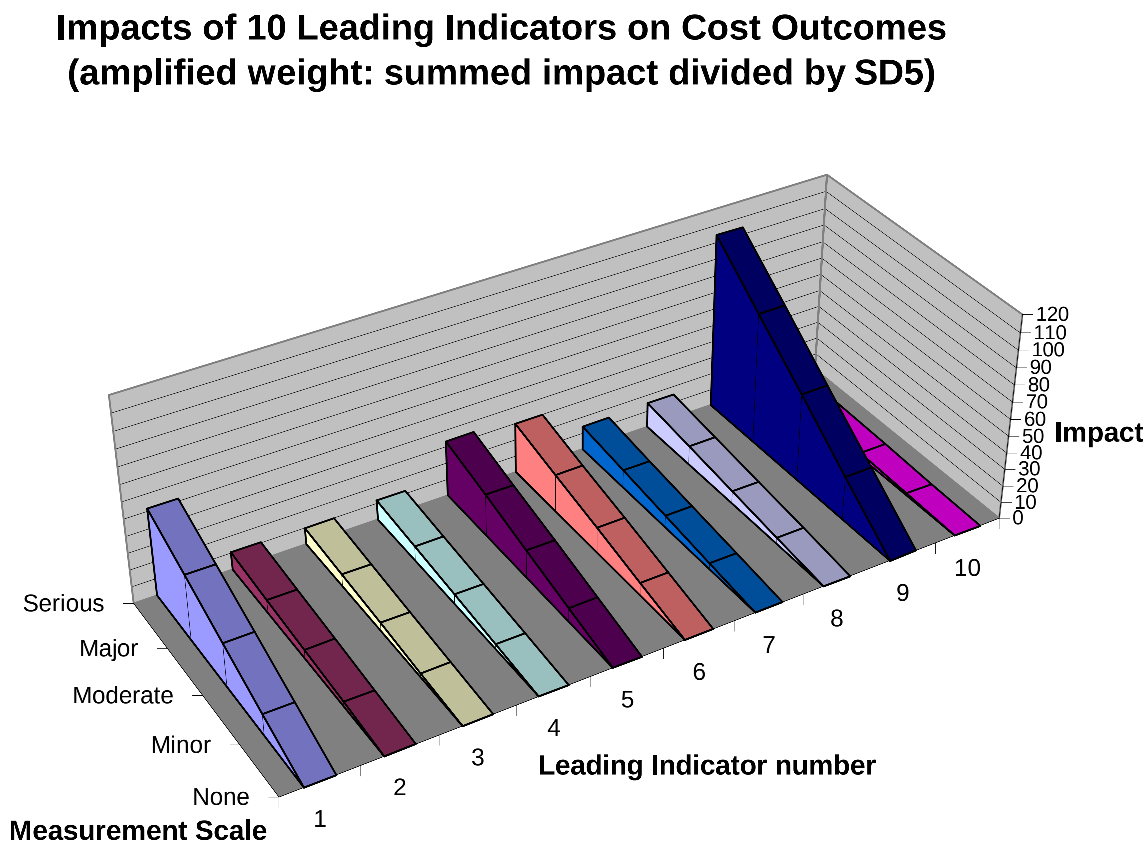


Figure 8. Weight Score Changes of 10 LIs for Cost Outcome by Amplified Weights

Finally, the research team members decided to allow users to choose one of the two options (normal or amplified weight) in the tool because the health scores generated by two different weights can aid in interpreting the outputs. This weighting method was adopted only for project outcomes because project practice groups solely represent potential problem areas that cannot be influenced by LIs in the other groups; thus, the normal weight was applied for generating project practice group health scores. Exactly the same process as generating outcome health scores from normal weight scores was used to generate outcome health scores from amplified weight scores.

Next, as the weight for the tool was decided, the hypothesis was tested. The hypothesis of the research was "The output scores of the new tool positively or negatively correlate to project outcomes such as cost performance and schedule performance". It was already confirmed in the previous section that the health scores were negatively correlated to the cost and schedule performance data. Figures 9 and 10 illustrate graphs that show negative correlation between health scores (cost and schedule) and project performance outputs.

Regression lines that best fit the data points were generated. For the cost correlation graph, linear regression line best fit the data points. On the other hand, polynomial regression line best fit the data points for the schedule correlation graph. The R-square for the cost and schedule outcomes were 0.682 and 0.7013 which are not very strong but definitely show correlation between the performance data and the health scores.

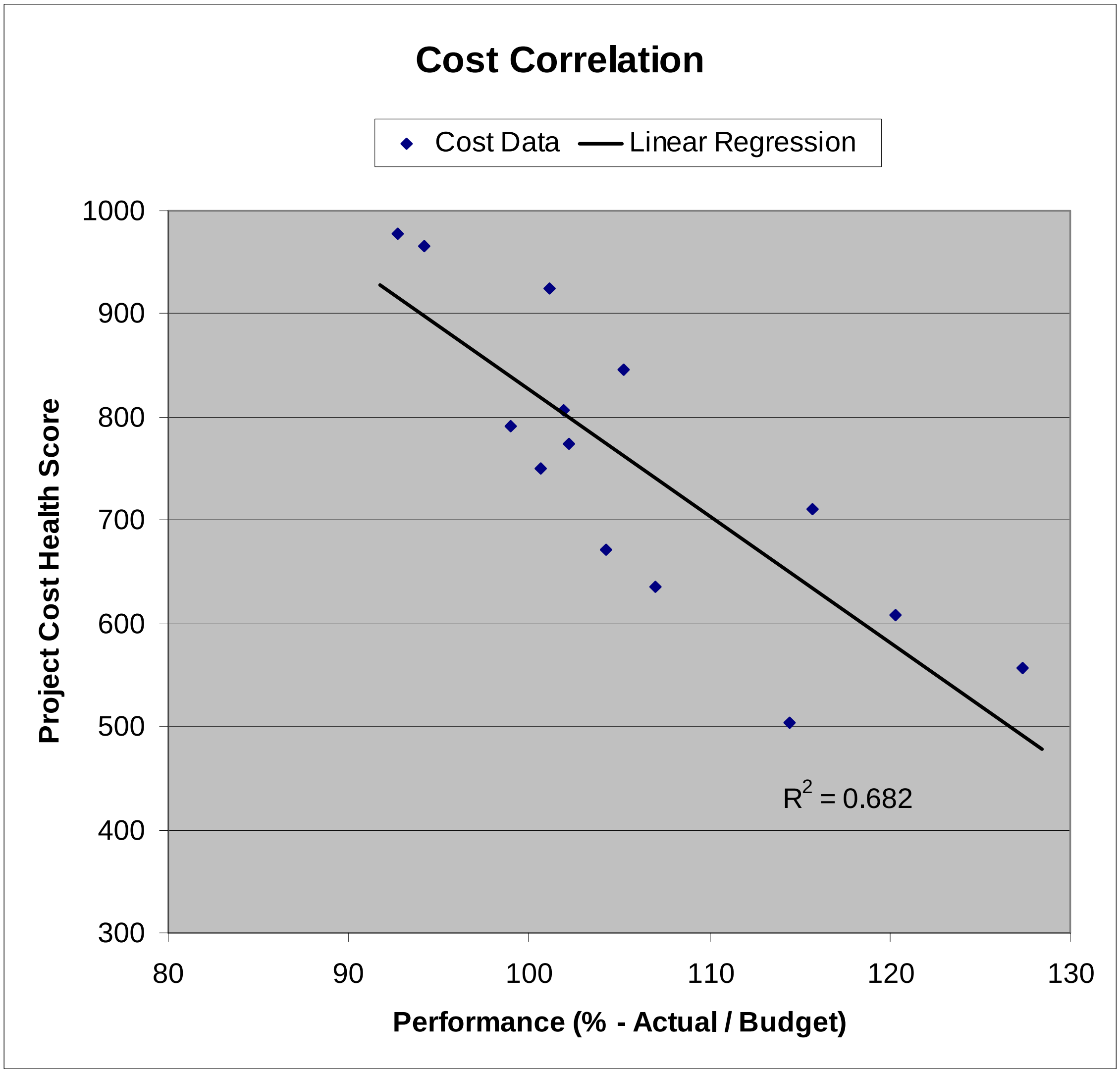


Figure 9. Negative Correlation Between Cost Health Scores and Project Cost Performance Outcome

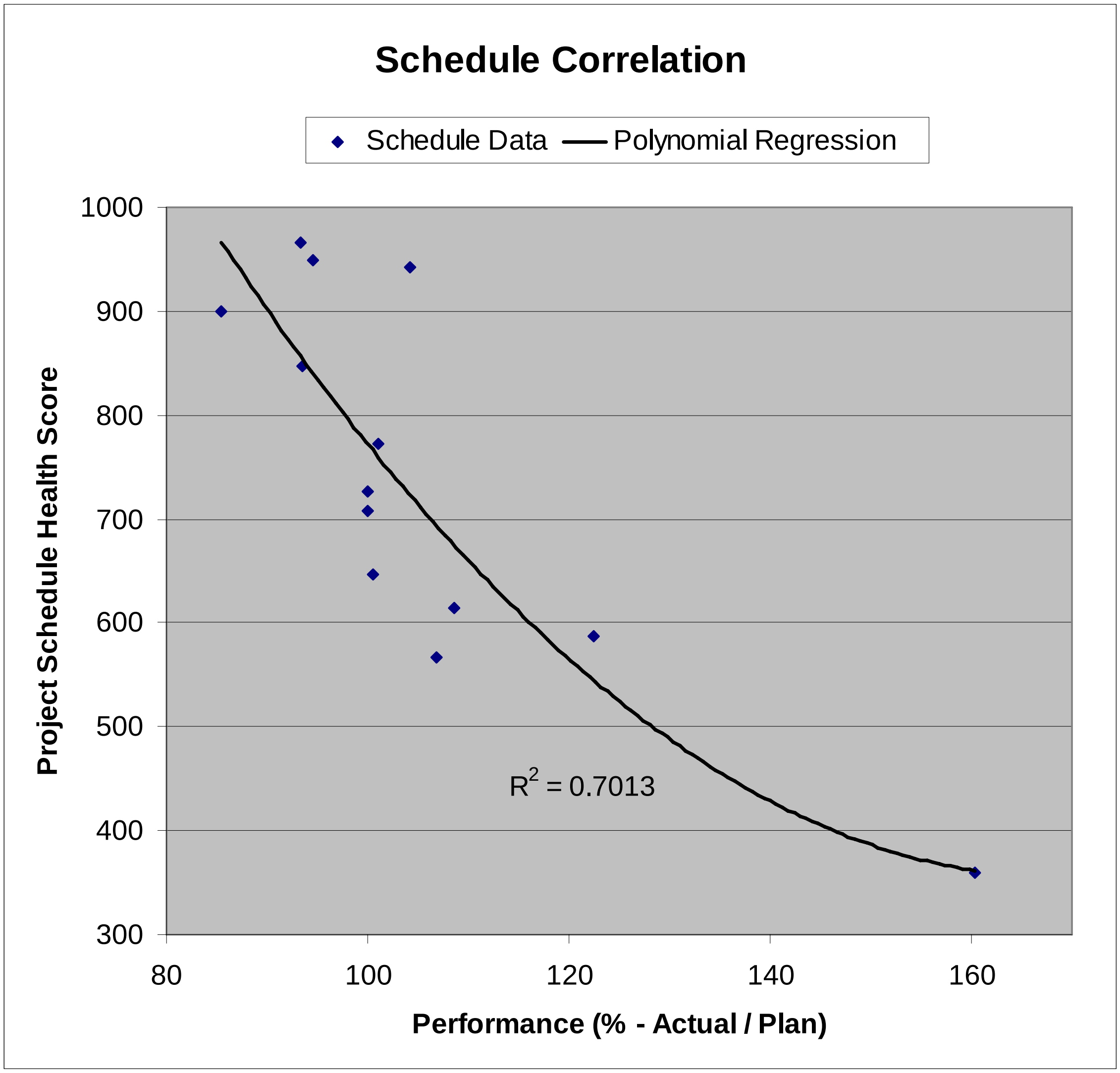


Figure 10. Negative Correlation Between Schedule Health Scores and Project Schedule Performance Outcome

5.11 Finalizing Tool

After the validation test, a couple of features in the tool were modified. The default color ranges of the output gauges were changed and a reset function was added in the input tab. Initially, the color ranges were set as one third, one third, and one third per color. After the correlation graphs were generated, it was noticed that a score below 700 indicates a 10 percent overrun in cost and schedule, which is considered high risk (red).

Therefore, a score below 700 was considered red. Although the health scores when projects met the planned cost and schedule were around 800, the research team members decided to divide the rest of the range into halves. Therefore, a score between 850 and 1000 was considered low risk (green), and a score between 700 and 850 was considered moderate risk (yellow). Figure 11 illustrates these borderlines in detail.

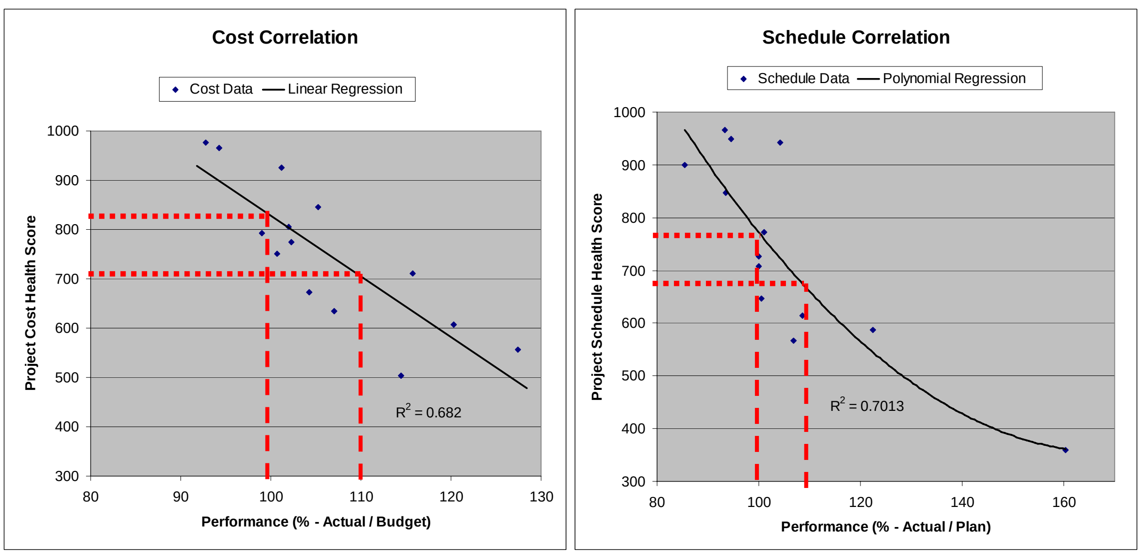


Figure 11. Project Health Score Correlation Graphs to Cost and Schedule

There was another consideration about resetting a choice that a user had already made. It was necessary when a user was uncertain as to whether or not a Leading Indicator was assessed correctly and the user wanted to change the input for the Leading

Indicator. Therefore, a button that restores the default status for the Leading Indicator was created for each LI. Other features of the tool are explained in the Chapter VI.

CHAPTER VI

PROJECT HEALTH INDICATOR TOOL DESCRIPTION

6.1 Description of Tool

The Project Health Indicator tool (refer to as PHI tool) uses Microsoft Excel and consists of six tabs: Introduction, User Guide, Input, Output -Outcomes, Output - Project Practices, and Customization. Each tab is described in detail with screen captures of the tab.

6.1.1 Introduction

The PHI tool is a Microsoft Excel file. Once the tool is opened, the "Introduction" tab will be shown. The user should read the introduction carefully before starting the evaluation. Figure 12 shows a screen capture of the introduction.

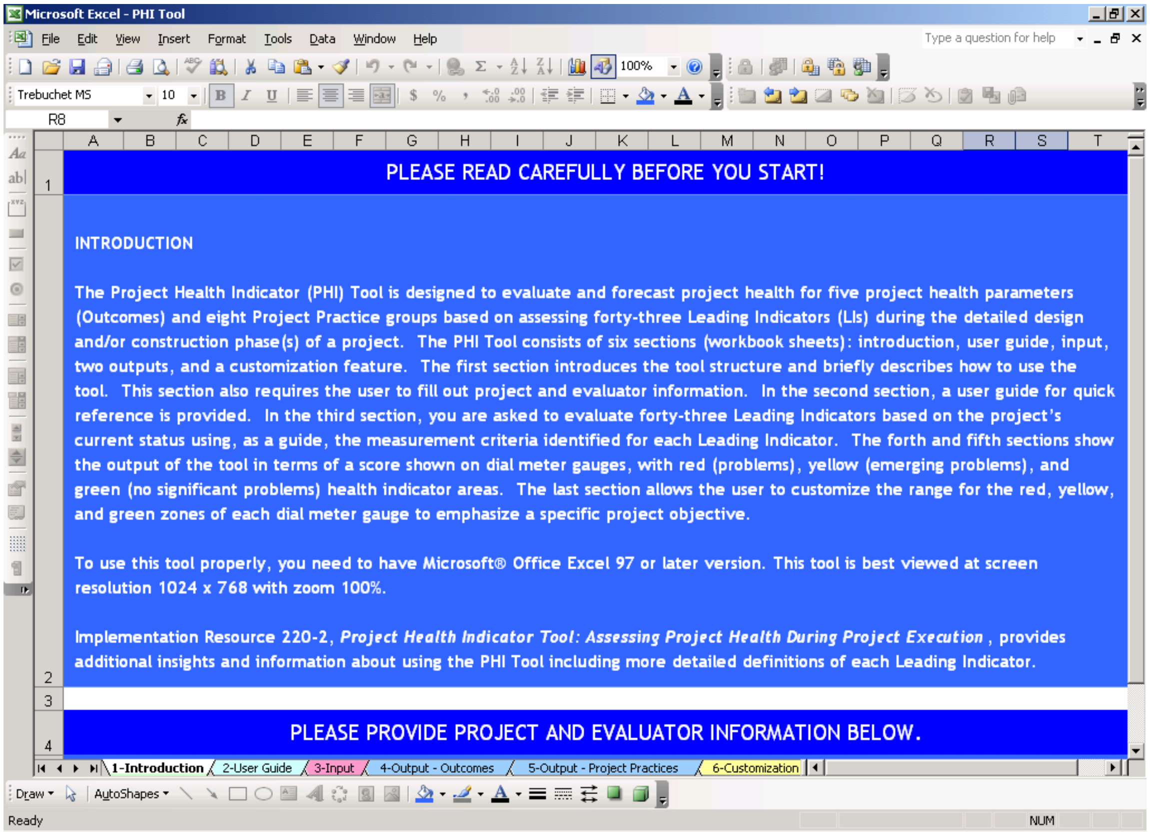


Figure 12. Screen Capture of "Introduction" Tab

After reading the introduction, the evaluator provides basic information about the project and evaluator. The information is automatically entered in the lower parts of the "Input," Output – Outcomes," and "Output – Project Practices" tabs for reference. Figure 13 illustrates a screen capture of suggested information when using the Tool. The user provides project and evaluator information.

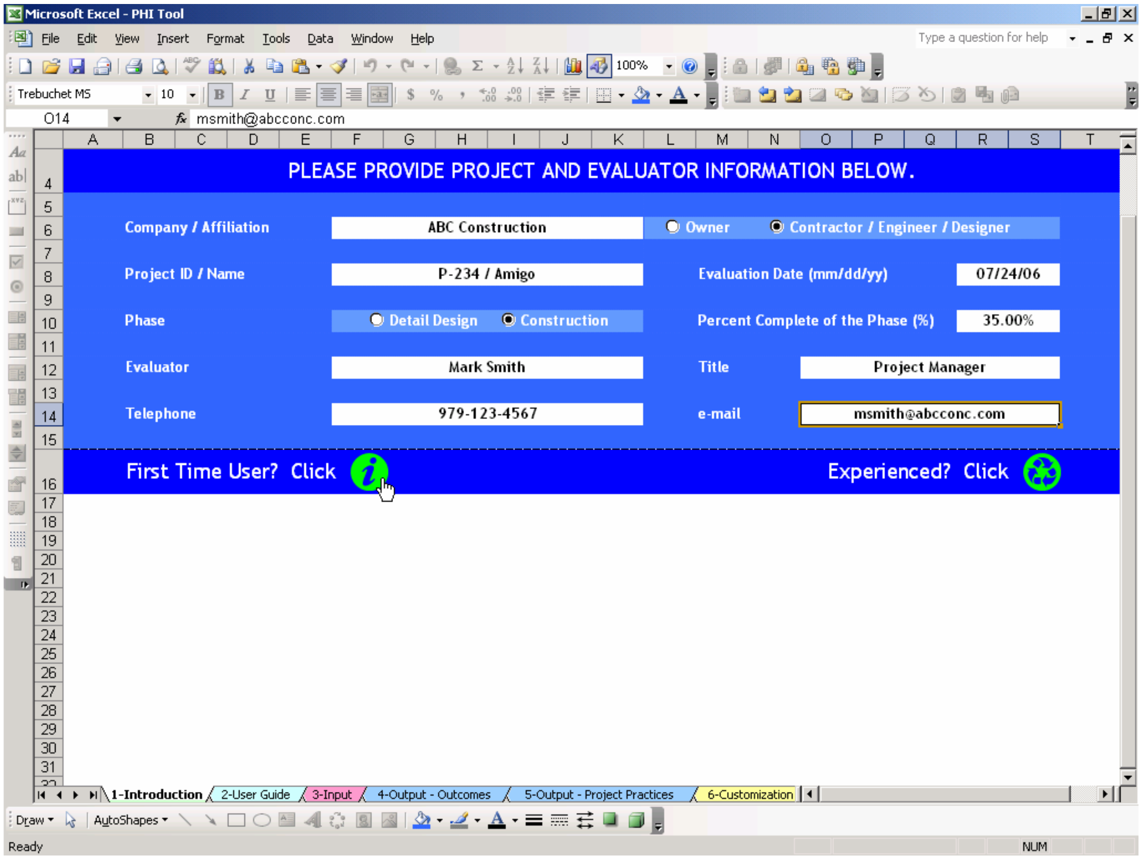


Figure 13. Screen Capture of Required Information in the "Introduction" Tab

After completing the project and evaluator information, the user is asked whether the user is a first time user or an experienced user. A first time user should click the green circle with letter "*i*" next to "First Time User?" and this will lead the user to the "User Guide" tab; alternately, the user may click the "User Guide" tab. An experienced user can click the green circle with three arrows next to "Experienced?" and this will lead the user to the "Input" tab, or the user may click the "Input" tab (see Figure 13 above).

6.1.2 User Guide

The “User Guide” tab includes useful tips for using the tool. This tab provides four basic tips: how to input, how to interpret output tabs, how to customize, and how to print the tool components such as results. Each tip gives specific information for quick reference. After reading the tips, the user should click the green circle next to “INPUT TAB” or just click the “Input” tab to start the evaluation of a project. Figure 14 is the screen capture of the “User Guide” tab.

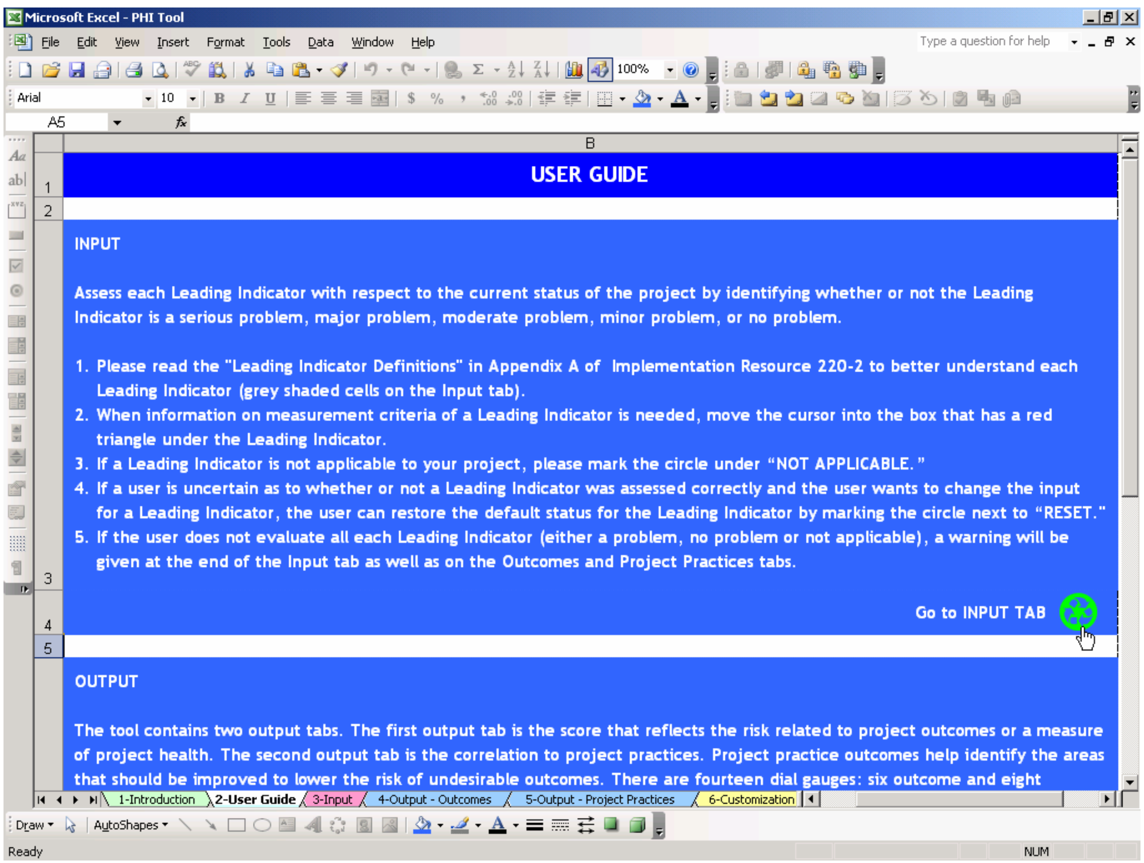


Figure 14. Screen Capture of the “User Guide” Tab

6.1.3 Input

Forty-three Leading Indicators are listed in the “Input” tab. The user assesses each Leading Indicator with respect to the current status of the project by identifying whether or not the Leading Indicator is a serious problem, major problem, moderate problem, minor problem, or no problem. Figure 15 shows the screen capture of the “Input” tab showing how to input an assessment of a Leading Indicator.

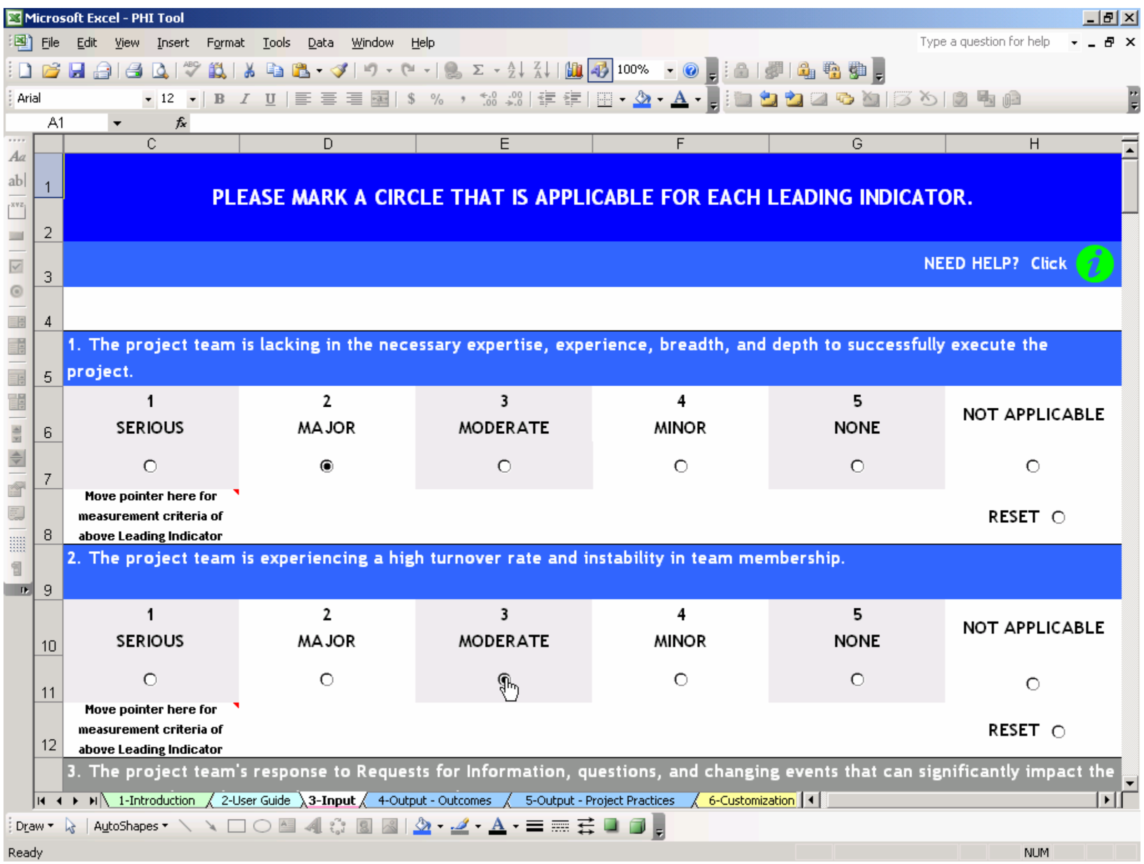


Figure 15. Screen Capture of the “Input” Tab

When more information on measurement criteria of a Leading Indicator is needed, move the cursor into the box with a red triangle in the upper right corner. Figure 16 is the screen capture of the "Input" tab showing how to view the measurement criteria of a Leading Indicator (see Appendix L for additional descriptive information for each LI).

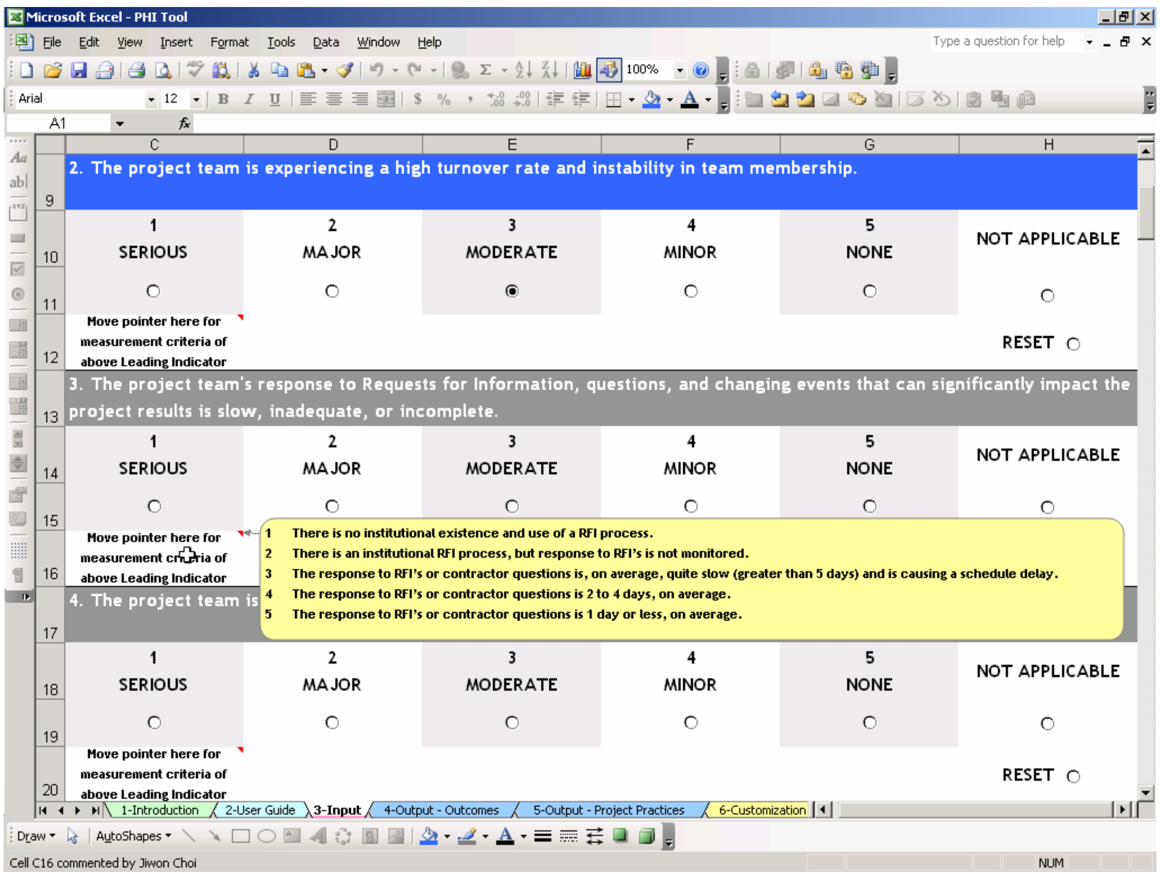


Figure 16. Screen Capture of the "Input" Tab with Measurement Criteria window

If a Leading Indicator is not applicable to the project, the user marks the circle under “NOT APPLICABLE,” and the grey box turns white. Figure 17 shows the screen capture of the “Input” tab showing a Leading Indicator that is not applicable for evaluation.

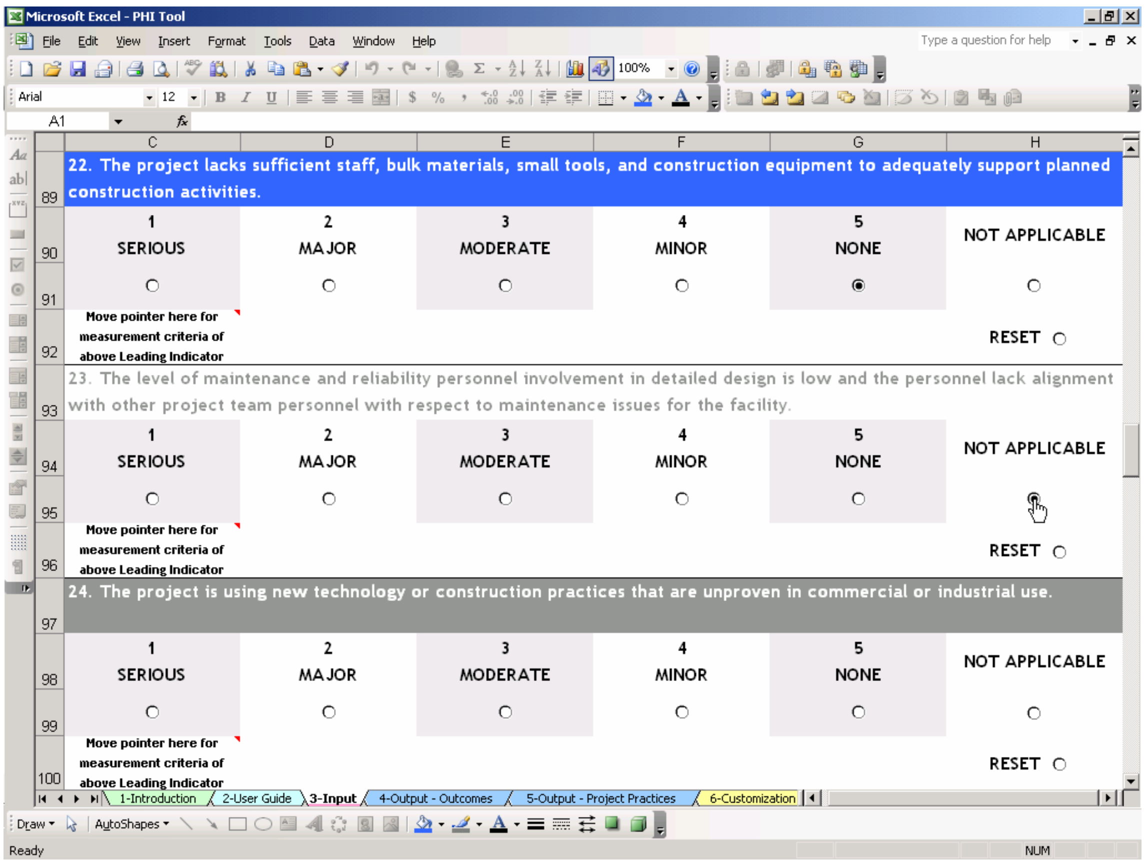


Figure 17. Screen shot of the “Input” Tab, “Not Applicable” Choice

If a user is uncertain as to whether or not a Leading Indicator was assessed correctly and the user wants to change the input for a Leading Indicator, the user can restore the default status for the Leading Indicator by using the “RESET” button. Figure 18 illustrates the use of the “RESET” button.

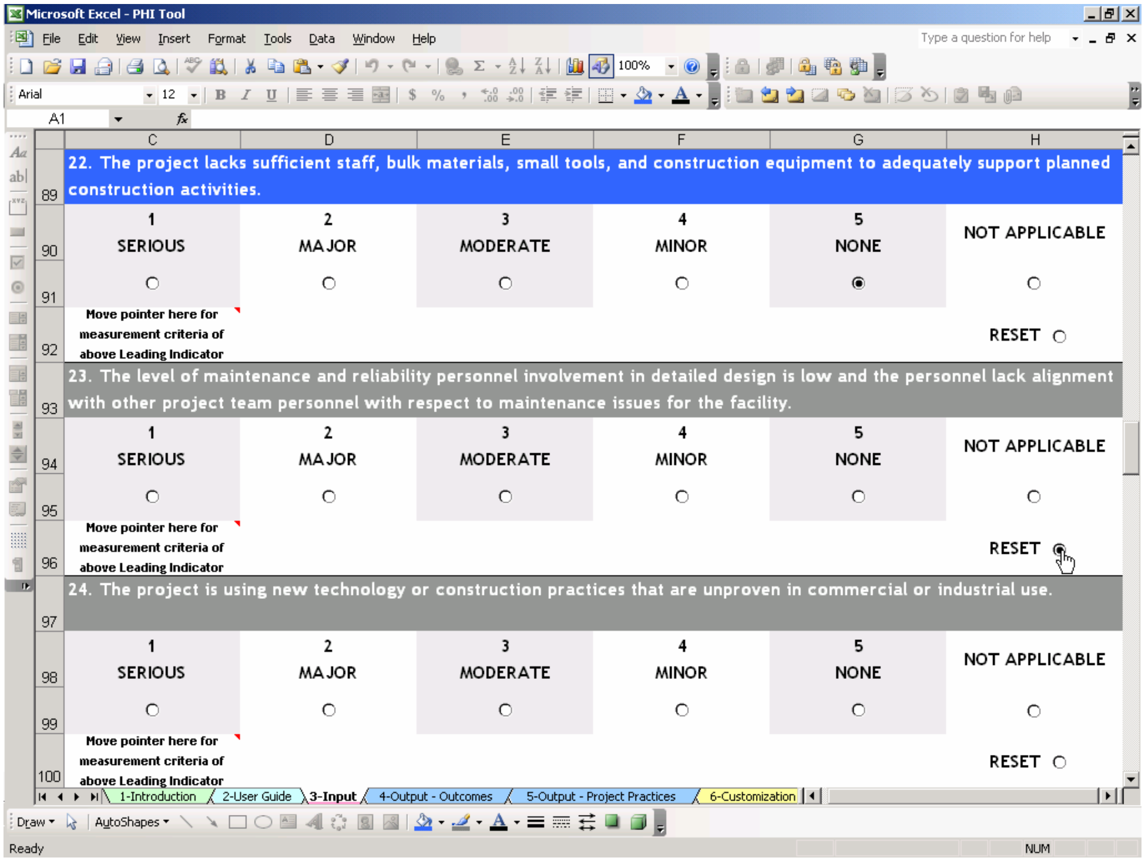


Figure 18. Screen shot of the "Input" Tab, "RESET" Choice

After completing an assessment of all Leading Indicators, the user goes to the "Output-Outcomes" and "Output-Project Practices" tabs to review the results. Figure 19 shows the screen capture of the "Input" tab showing that the evaluation has been completed.

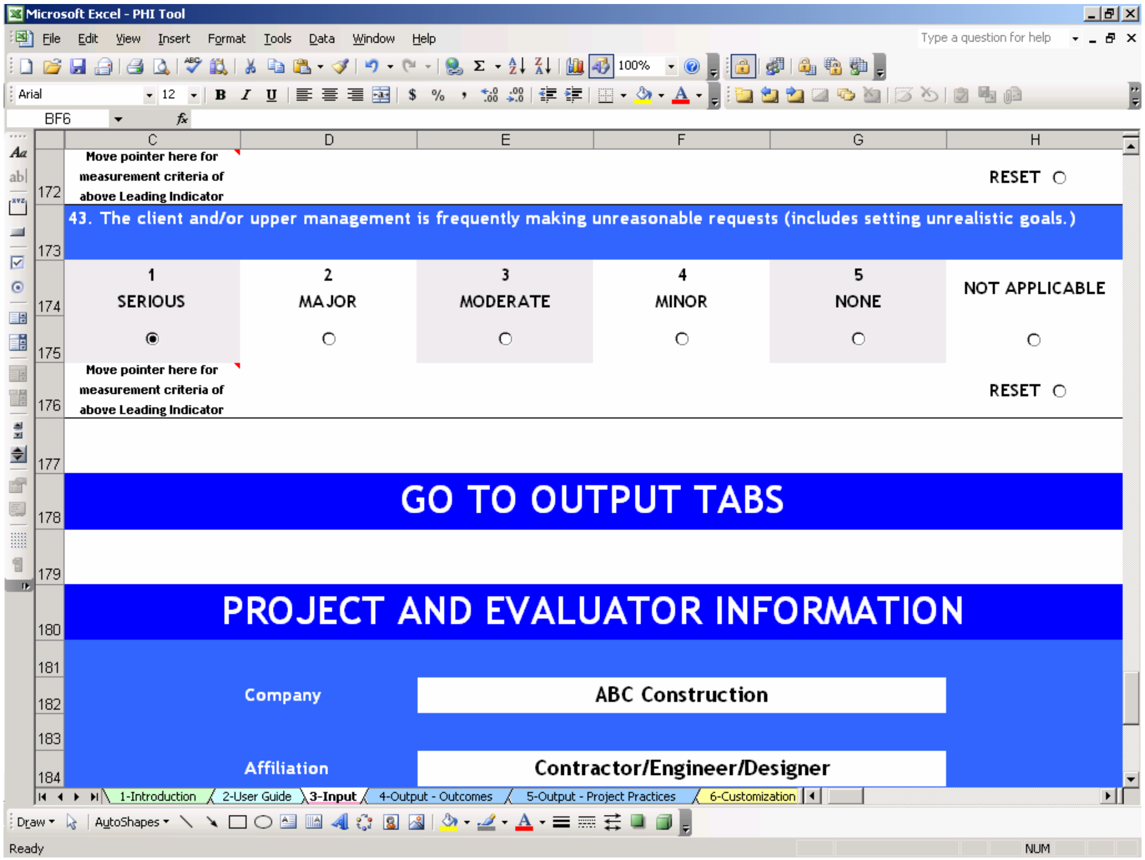


Figure 19. Screen Capture of the "Input" Tab that has been completed

If there is/are Leading Indicator(s) that is/are not assessed, a notice will appear at the very bottom saying that "00 (a specific number) Leading Indicator(s) was/were not assessed." The notice will appear in the middle of each outcome tab as well. Figure 20 shows the screen capture of the "Input" tab showing that two Leading Indicators were not assessed.

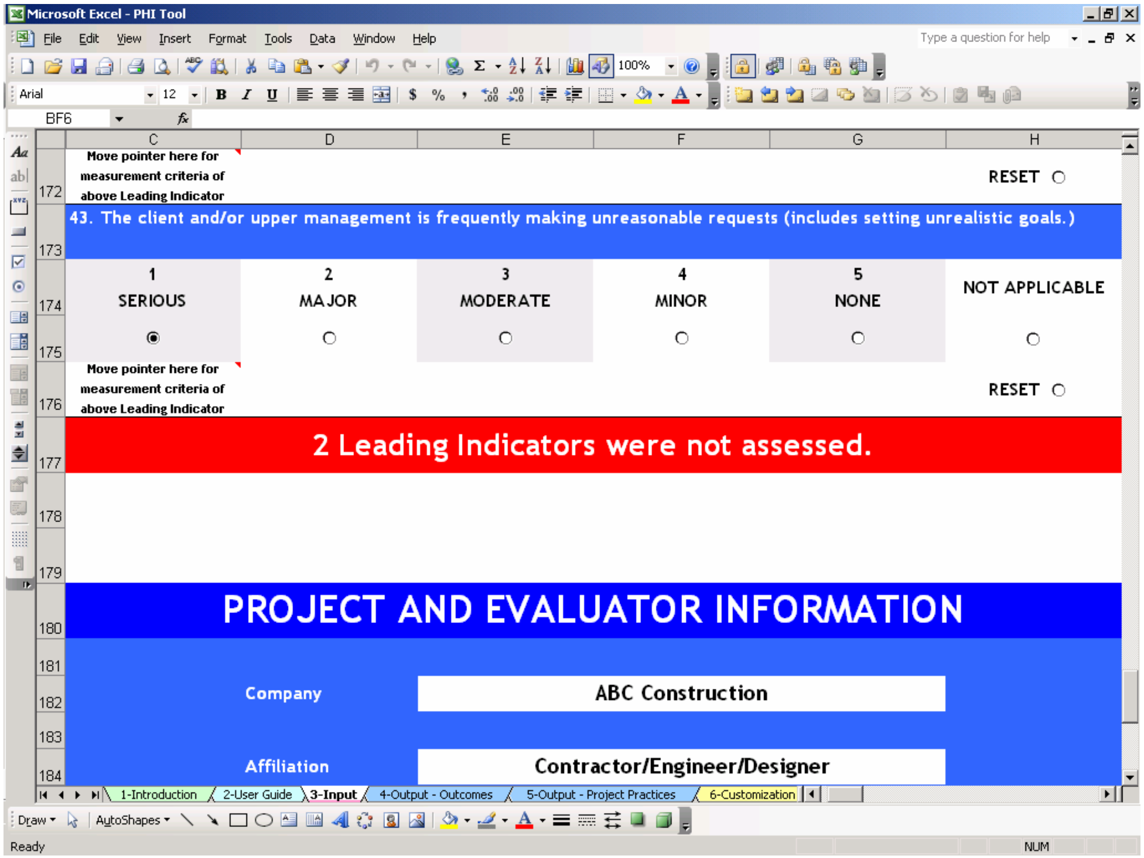


Figure 20. Screen Capture of the “Input” Tab that two leading indicators have not been assessed

Figure 21 is the screen capture of the “Output-Outcomes” tab showing that two Leading Indicators were not assessed.

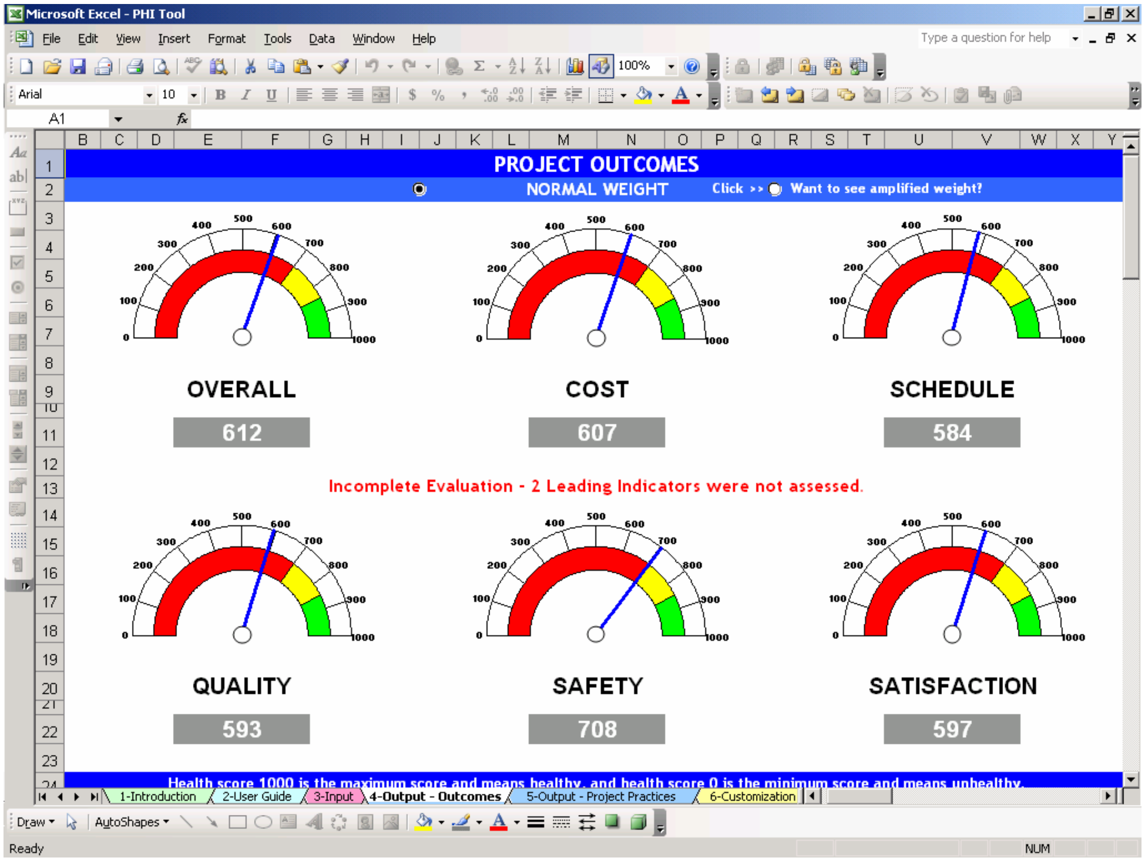


Figure 21. Screen Capture of the "Output - Outcomes" Tab

6.1.4 Output Outcome Gauges

There are six Outcome dial gauges: overall and five outcomes under this tab. The needles move based on the evaluation made under the "Input" tab. As noted in the health score and weight section, users can select one of the two weight options, normal or amplified, for project outcome gauges. Figure 22 is the screen capture of the "Output-Outcomes" tab depicting one overall and five outcome gauges with the selection of normal weight, which is a default setting for the tool.

The Schedule Outcome gauge indicates that problems exist that may impact meeting the planned completion date. To review the impact of the amplified weight on the health scores, the user clicks the right circle of the two circles at the top of the tab. Figure 23 is the screen capture of the same tab with the selection of the amplified weight. The health scores based on the amplified weight are not significantly different from the normal weight in this case, but under some circumstances the amplified weighting may differentiate outcomes more vividly.

With the health scores generated by two different weights, users can, perhaps, interpret the outputs more accurately. For example, the biggest difference between the two weights lies in safety outcomes. As shown in Figures 22 and 23, the safety health score difference is 234. Because many of the 43 LI's have some impact on safety (actually only a few have a high impact), the poor ratings on Cost and Schedule impacted safety indirectly with the normal weight. With the amplified weight, however, these Cost and Schedule impacts were reduced, thereby raising the safety score. This could mean that if a user has a safety concern for a project despite the high safety health score, the user could use the normal weight output tab and vice versa.

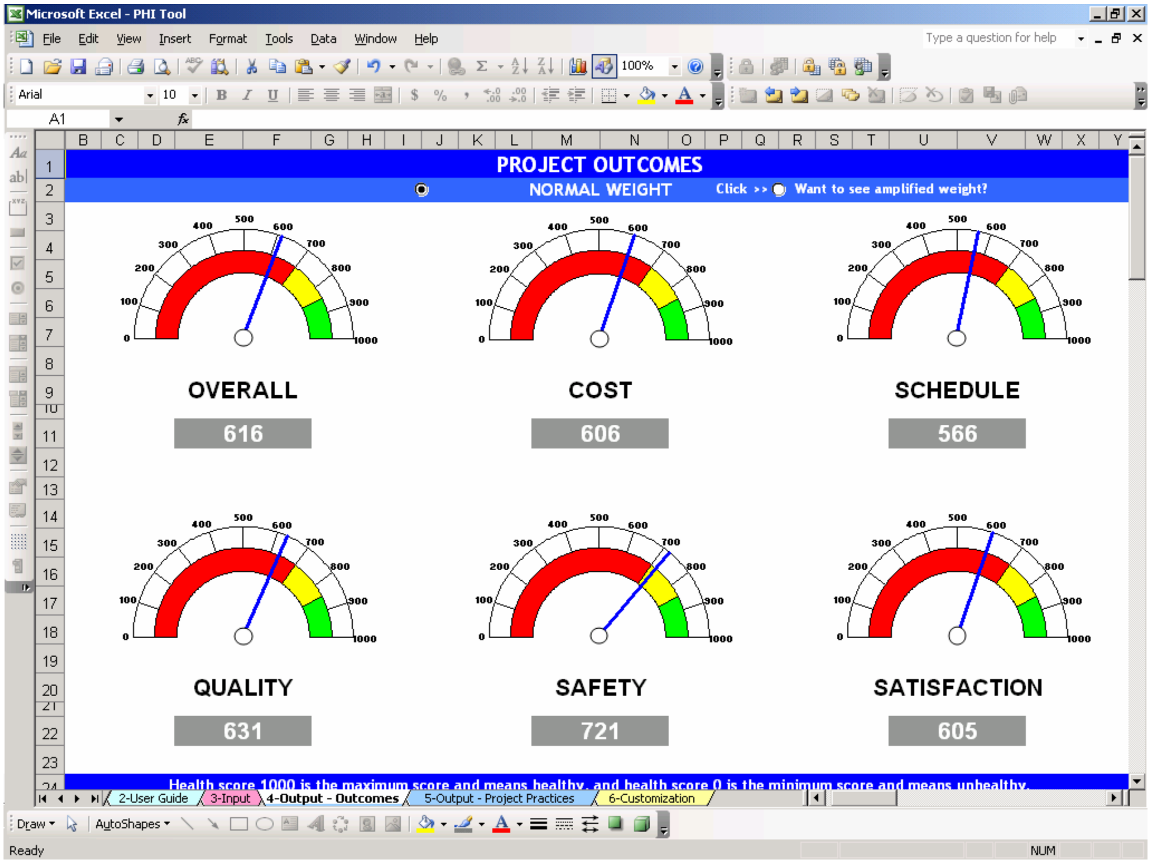


Figure 22. Screen Capture of the "Output - Outcomes" Tab with Normal Weight

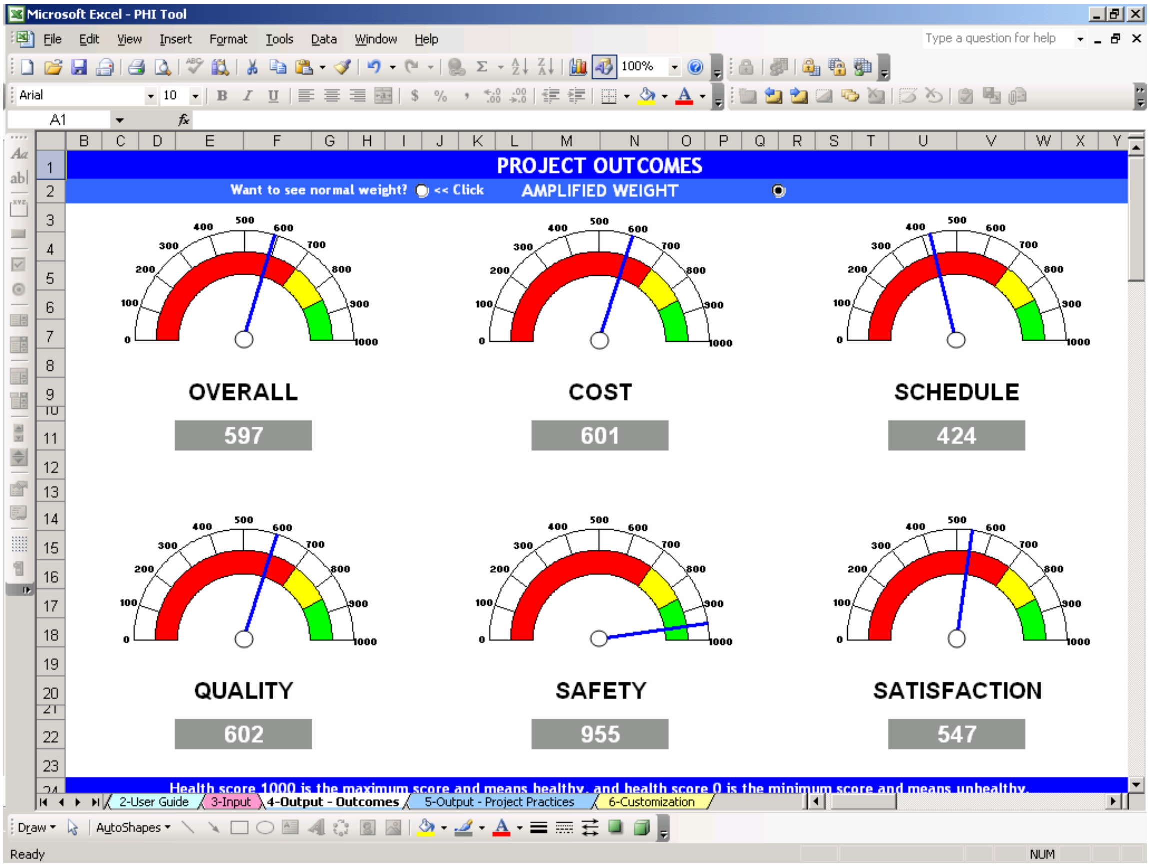


Figure 23. Screen Capture of the "Output - Outcomes" Tab with Amplified Weight

6.1.5 Output Practice Gauges

There are eight Project Practice dial gauges corresponding to alignment, change management, constructability, contracting, quality management, safety practice, project control, and team building. The needles move based on the evaluation made in the "Input" tab. The concept of interpreting the dial gauges is the same as that of outcome gauges. There is no option for weighting. Only normal weight is used for the calculation. Figure 24 illustrates the screen capture of the "Output - Project Practices" tab showing eight practice results.

In this example, Project Control reflects problems as the gauge is located in the red band. These results are reflected in the overall impact on the Schedule Outcome discussed earlier as shown in Figures 22 and 23 (red band indicating potential problems). The interpretation of the results, however, can be different from company to company and person to person. Therefore, the ranges can be adjusted by users according to different project objectives, as required. The user then would examine those LIs in the Project Control Practice area to identify potential problem areas within the project (see Appendix M).

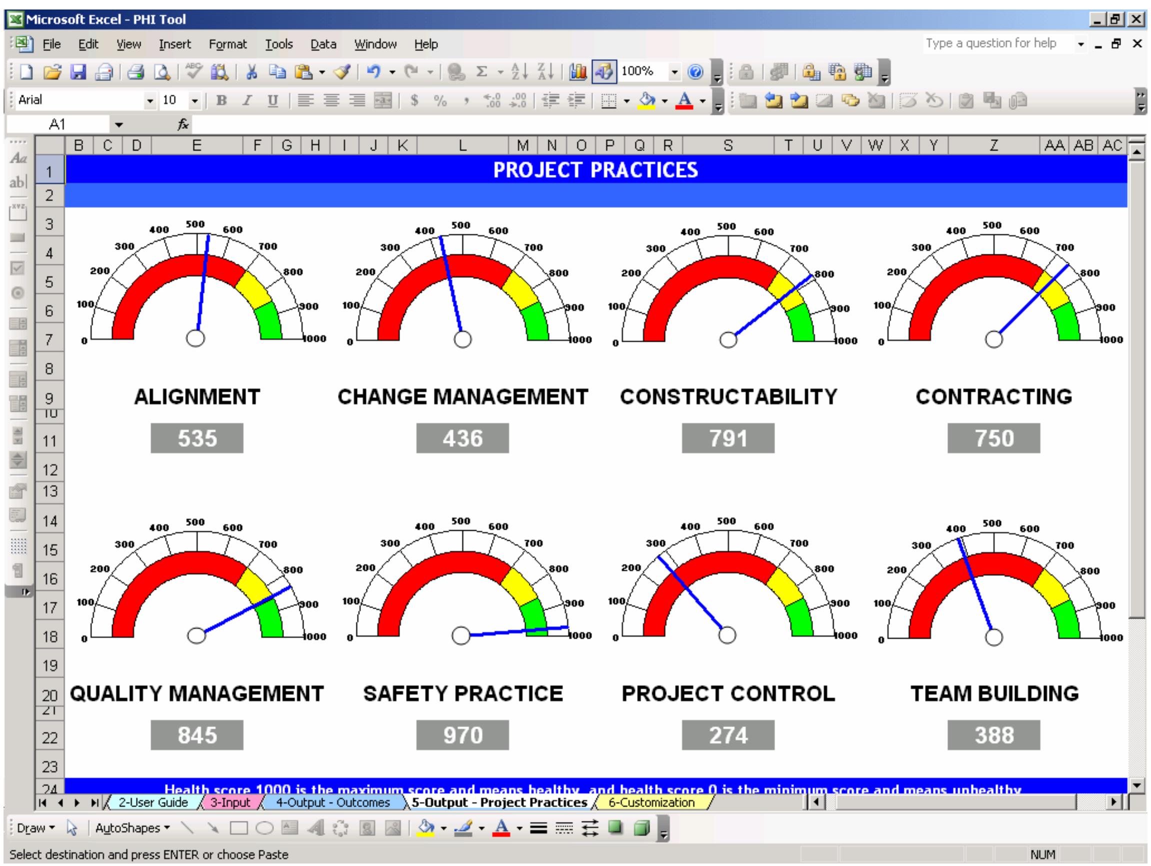


Figure 24. Screen Capture of the “Output - Project Practices” Tab

6.1.6 Customization of Outcomes Sensitivity

The user may customize the tool by setting dial gauge calibration prior to the first use of the tool, during front end planning. The calibration should be aligned with the project objectives. If the project is schedule driven, the schedule outcome gauge would be calibrated, so that the green range is narrower with respect to the yellow and red ranges. This will help draw attention to the relative importance of the schedule outcome and raise an earlier warning flag should the leading indicators begin to reveal a schedule slippage impact. The value in the calibration step is to:

- reinforce the project objectives;
- align those objectives with the project outcome gauges; and
- direct attention to the critical project objectives during tool use.

To do so, the project team can adjust for outcome sensitivity using the customization tab shown in Figure 25.

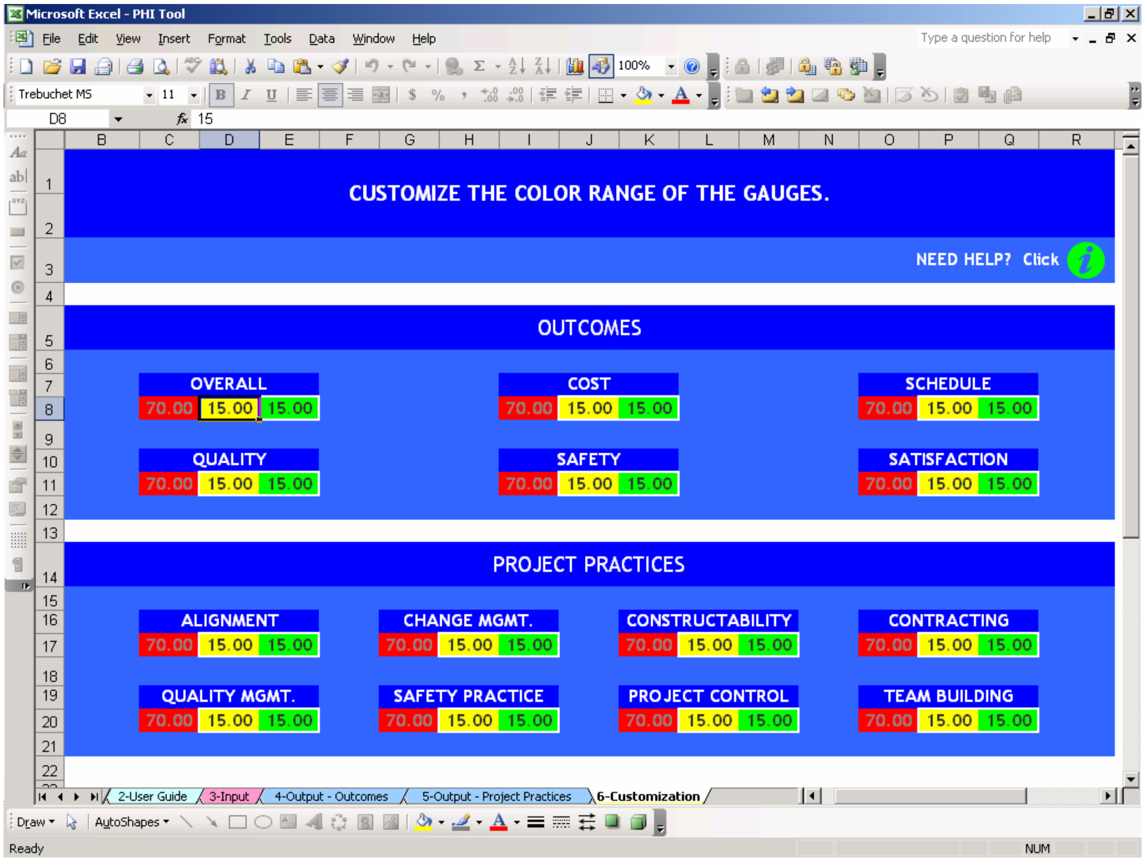


Figure 25. Screen Capture of the “Customization” Tab

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The primary goal of the research was to develop a new tool that can forecast the potential risk of not meeting specific project outcomes based on assessing leading indicators. To accomplish the goal, forty three leading indicators were identified through three surveys asking industry professionals about potential leading indicators and their negative impacts on project outcomes. Secondly, exact negative impacts of leading indicators on project outcomes were calculated. Thirdly, the PHI tool that can evaluate the risks to project outcomes and suggest areas for improvement was developed based on the calculated negative impact of the leading indicators on project outcomes. Finally, the PHI tool was validated by testing actual projects and negative statistically significant correlation was observed between project outcomes and health scores generated by the tool.

7.2 Recommendations

Although the research team developed the PHI tool that can identify potential risks for a project during a project execution phase, research team members agreed that further research is needed to complete the PHI tool. First of all, performing a long-term case study for an actual project is necessary. The primary purpose of the PHI tool is to identify potential risks in advance during a course of project execution. Therefore, testing the PHI tool for an actual project was required but limited time for the research did not allow long term test of the PHI tool.

Secondly, validating the tool using more data is necessary. During the validation process, the research team could not collect enough data for the tool validation test due to some restrictions that were discussed already. Fortunately with the fourteen projects, negative correlations between tool output and actual project performance data was observed. If more data were obtained and tested, the validity of the tool, using the same method, would likely provide users with more confidence when using the tool.

Finally, integrating features that would help resolves problems identified by the tool would improve interpretation of tool results. The PHI tool was developed to be a simple and easy to use but effective tool, and these necessities were accomplished. In other words, users can identify potential upcoming problems of a project by using the tool.

However, the PHI tool does not have integrated features that help users find the sources of problems identified by the tool. Although there are some tips and materials that provide users with preventive measures for potential problems or risks of poor project performance, these measures are conducted manually and, therefore, a users' immediate action to deal with the problems is difficult to perform. Thus, developing the PHI tool with more integrated features that would help identify the source of problems and provide improved interpretation of the results would also deserve further study.

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APPENDIX A

Research Team Membership

Leading Indicators to Project Outcome Research Team Membership

Kevin J. Gierc,	Dick Corporation,	Chair
Paul Ennis,	U.S. Steel,	Co-Chair
Stuart D. Anderson,	Texas A&M University	
Robert H. Briest,	ALSTOM Power, Inc	
David Campbell,	Air Products and Chemicals	
Jiwon Choi,	Texas A&M University	
William Chumchal,	Mustang Engineering	
Ian D. Etzkin,	CDI Engineering Solutions	
Gilles L. Gelinas,	DuPont Canada Company	
Stephen E. Goodman,	J. Ray McDermott, Inc	
Robert MacLaren,	Ontario Power Generation	
Michael G. Pappas,	Eastman Chemical Company	
Steven D. Rench,	ConocoPhillips	
Mike Sheridan,	International Paper	
Brian E. Sichter,	CB&I	

Past Membership

Michael Bronkowski,	Amgen
S. J. Kim,	Texas A&M University
Minesh Kinkhabwala,	Aker Kværner Pharmaceuticals
Don G. Miller,	Gilbane Building Company

APPENDIX B

List of 181 Potential Leading Indicators

LI No.	Potential Leading Indicators
1	Cash Flow drives project planning
2	Responsibility for who will prepare budget estimates and the frequency of estimate updates is clearly defined.
3	The level of detail and what is to be included within the presentation of any budget estimate is clearly defined.
4	Appropriate qualifications and assumptions are defined within the budget estimates prepared for each design phase milestone
5	Budget estimates are provided on time and at the level of detail and in the format established during the PPP phase
6	Consistency in budget estimating of construction and soft costs at each design phase milestone.
7	Appropriate percentage of Contingency, consistent with the level of design development
8	Competitive pricing of overall project or bid packages is consistent within groups of similarly qualified bidders.
9	If allowed by the bid process, bidder clarifications and qualifications to bid pricing are consistent and well defined.
10	Bidder interest and coverage is sufficient/appropriate for the type of project.
11	Issues with potential cost exposure are accounted for within the cost control system immediately upon recognition.
12	Cost issues are resolved expeditiously. A process exists and is utilized, without deviation, to designate proceed changes from those issued only for pricing/consideration.
13	Project Management knows that by immediately recognizing potential cost issues the cost report slightly overstates the anticipated final cost of the project
14	Scope change pricing is reasonable and does not require extraordinary effort to negotiate and agree on value
15	Final Project cost report has been issued.
16	Financial stability of various companies comprising the project team
17	Material Price changes
18	Foreign Exchange
19	A milestone schedule exists from day 1 of the process. Every phase should be identified with

	realistic time frames assigned with identified multiple milestones
20	Project Master Schedule is included within bid documents.
21	The availability of Contractor information to confirm Master Schedule assumptions.
22	Responsibility for who will develop the project schedule and frequency of updates is clearly defined.
23	A date is established for when a detailed schedule is to replace the initial milestone schedule.
24	The schedule has not been "backed into" by blind adherence to executive mandates. Scheduling is done with fixing the end date.
25	Manpower information obtained as part of bid process supports Master Schedule durations and sequence/phasing of construction.
26	Bid and award times are consistent with the schedule durations assigned during prior project phases.
27	Schedule updates are performed with the frequency identified within the PPP phase.
28	A legitimate method of determining progress on each schedule activity exists and is utilized without exception
29	The schedule "feels right" in comparison to observable progress on the site
30	Updated schedule review is an agenda item at every team meeting following an update. The discussion is focused and effective.
31	Look-ahead schedules are regularly and effectively used.
32	When schedule activities are statused as complete they are 100% finished not "substantially complete".
33	Schedule durations defined in prior phases are being maintained.
34	Follow on warranty inspections are identified and date(s) of inspection(s) are documented
35	The ratio of repeated schedule slippage
36	Detailed scheduling is developing or has concluded per the plan defined within the PPP phase.
37	If schedule input is obtained from outside sources, they have been given sufficient information to provide legitimate input to your schedule, not just enough information to have them tell you what you want to hear.
38	The design phase milestones are being met. Milestones for future phases are tested regularly for impact from factors beyond just the progress of the current phase
39	% of design completion at commencement of procurement and construction

40	A well-defined project objectives and business goals
41	The degree of knowing project objectives among team members
42	Ability/inability to quickly and succinctly articulate main project goals
43	Contract Change during project
44	Change in contracting strategy
45	Change in site location
46	Thorough scope review is performed with bidders prior to award (if allowed by Owner's procurement practices).
47	Exclusions from scope by bidders are identified and quantified for later procurement.
48	Contractor requests for time extensions associated with scope changes are realistic in nature and supportable.
49	The schedule is revised to reflect scope change impacts as soon as the change is recognized.
50	Sufficient good will/trust exists to allow for changes in scope to be incorporated into the ongoing construction regardless of the status of formal contract amendments
51	Scope change process is clearly defined and agreed to by all parties.
52	Identify the difference between scope change and design development.
53	A process exists and is followed to evaluate the impact of scope changes on all aspects of project (cost, schedule, etc.)
54	Based upon analysis of the process above, the impacted aspect is adjusted.
55	Process for issuance of bid addenda is well defined with responsibilities clearly understood by team members.
56	Bid addenda are clear and complete. Appropriate level of documentation is provided.
57	Failure to freeze to scope
58	Final change orders have been written, retainage released and Trade contracts closed with final lien releases obtained.
59	Scope(s) of work exist for all bid packages complimenting the contract document set.
60	Project buy-out is completed quickly.
61	In multiple bid package procurements every item of work is assigned to a bid package.

62	Scope busts are recognized well in advance of schedule impact. There is a direct tie here to effective look ahead schedule use.
63	Start and end dates for all warrantees are identified and documented to all Project participants.
64	Bid RFI's are few and issues raised within are easily addressed. Large numbers of RFI requiring significant document clarifications/revisions are a sure sign of future project problems.
65	RFI's are used for their legitimate intended purpose by all team members (no change order hunting or backdoor scope changes).
66	Emergency RFI's (same day/1 day turn around) are the exception not the rule.
67	RFI responses are complete the first time around and do not require follow-on clarifications/RFIs.
68	Engineering response time to field RFI
69	Engineering Deliverables IFC Deviation from Schedule
70	Weather conditions - acts of God
71	Significant Public Events
72	War
73	Cultural Barriers
74	Review agencies (internal & external) are identified and responsibilities for review parameters of each agency are defined
75	The number and nature of design reviews is defined.
76	Process and responsibility for documenting and compiling design review comments is defined.
77	Internal design reviews and approvals are completed on time and are meaningful and complete in a format agreed upon by the project team.
78	Documents have progressed to the appropriate level for external design reviews to be performed and feedback received. No issues exist with the authorities having jurisdiction relative to design.
79	The ratio of Engineering/Design/Fabrication errors
80	An agreed upon, job specific, definition of "quality" exists.
81	A clearly defined plan, identifying who has input on quality issues, who collects the information and who has the final say on issues of dispute exists.
82	The PPP phase requirements are being met. Conflicts/concerns are addressed without significant change to the developing documents.

83	A project specific 'Quality in Construction" plan is developing commensurate with the balance of the document set. All project participants roles and responsibilities are defined within the plan.
84	Project specific QIC plan is included within bid documents. Front end documents contain appropriate flow down information so that plan can be enforced during follow-on phases.
85	The requirements of the QIC plan are being followed. There is legitimate participation from all parties identified within the plan.
86	By completion of the design phase there are no conflicts between the requirements of the project specific QIC plan and individual sections of the project specification/documents.
87	Deficiency items are corrected immediately following identification if possible, or a corrective action plan is developed for future implementation.
88	There is generally agreement on what items are considered deficiencies.
89	Closeout information begins to be compiled and submitted for review.
90	Terrorism
91	Safety Incidents
92	Design reviews (particularly constructability reviews) include an analysis of safety/loss prevention considerations by qualified personnel.
93	All project participants are active in safety inspection, awareness and education.
94	Confrontation regarding safety issues are either non-existent or are resolved immediately with the full support of project participants.
95	Drastic action associated with non-compliance issues (fines, dismissals, work stoppages) are non-existent.
96	A choice never needs to be made between productivity/schedule and safety.
97	Big picture issues such as use of a wrap-up insurance program, project medical team, project safety officer, outsourcing of safety compliance inspections, etc. are made so decisions can be properly reflected in the procurement package.
98	Responsibility for preparing a project specific safety plan is assigned for inclusion within the procurement package(s).
99	The project specific safety plan is developed to the same extent as the balance of the design.
100	Project specific safety plan is included within bid documents. Front end documents contain appropriate flow down information so that plan can be enforced during follow-on phases.
101	The requirements of the project specific safety plan are followed without exception.

102	Maintain project specific safety plan requirements during commissioning phase.
103	Near misses
104	Mixed team - owner engineers and contract engineers
105	Hidden agendas within Project Teams
106	Interdisciplinary meetings are frequent, productive and well attended.
107	Outstanding action items, responsibilities and results are well documented.
108	The same action items keep showing up again and again
109	The rate of increasing action items
110	Local Resource availability. Competition from other local projects, competition on wage rates
111	Co-occupancy. Projects competing for space
112	Manpower, materials, tools & equipment are consistently available when needed for planned activities without extraordinary effort.
113	Local economic conditions
114	Push to meet market window
115	Political Unrest
116	Subcontractors or supplier financial health & capability to work
117	Backcharge items are either non-existent or are resolved immediately.
118	Project Closeout deliverables have already been submitted reviewed and approved so that the only remaining action is to transmit.
119	All documentation is accurate and issued timely.
120	Pre-commissioning performance testing and inspections are legitimately completed before commissioning begins.
121	Commissioning activities were identified in PPP & Design phases and modified as required by scope changes during construction.
122	Maintenance issues are not being masked as closeout requirements.
123	Proven technology or not
124	Procurement strategy is developed and implemented for all services being outsourced and in-house resources are identified and committed to the project.

125	A facilitator is identified and responsibilities are agreed to and understood.
126	Facility (Using Agency) personnel with project involvement are identified.
127	Facility (Using Agency) Program needs and concerns are identified.
128	Facility program needs identified in PPP phase have been addressed. Program needs remain consistent throughout design phase.
129	Facility personnel are included in scope review sessions with bidders.
130	Frequent inspection by Facilities personnel.
131	Facilities personnel are involved in submittal review and approval process.
132	Facility personnel are regular, contributing attendees at project meetings.
133	Facilities personnel are an integral part of the commissioning team.
134	Facilities departments are adequately represented at commissioning events or have a realistic plan to share information/training beyond the direct participants.
135	Attic stock has been identified. Owner is aware of quantity of material and has identified storage space of adequate size.
136	Facility engagement beyond core project team
137	The facilitator confirms the availability of all necessary participants immediately prior to each commissioning event.
138	Proprietary items are identified and documented.
139	Missed requirements are identified during design reviews and addressed.
140	Every issue has a response time associated with it for each action item.
141	Response times are met consistently or adjusted for changing events in real time not after a date has been missed.
142	Lien releases are consistently provided.
143	Material supplier information is made readily available.
144	No emergency requests for material substitutions/approval of alternate suppliers materials.
145	Mixed team - owner engineers and contract engineers
146	Team Member personal problems
147	Change in project team membership

148	Team Quality - Expertise, experience, bench/depth, supervision provisions
149	Experience level of the Project Manager or Team Leader
150	Project participants are not reassigned prematurely and/or sufficient knowledgeable personnel are left in place to maintain corporate knowledge
151	Language Barriers
152	Misled by Contractor
153	Misled by Owner
154	Approval authority levels are clearly defined.
155	Well-defined Organizational Breakdown Structure
156	Correspondence/discussion between parties is focused on resolution of project issues not on the documentation of problems
157	Communication channels among related parties
158	Determination is made on the delivery system to be utilized for the project.
159	Determination is made on what methods of team building (I.e. partnering) if any will be utilized.
160	Bid RFI's are few and issues raised within are easily addressed
161	Project personnel are not working excessive hours.
162	There is stability in project personnel.
163	Sense of project loyalty/success is equal to the sense of company success/loyalty
164	Parties regularly attend and make contributions to team meetings.
165	Meetings are short and productive. They accomplish their defined purpose.
166	Meetings are not required for issue resolution to move forward.
167	There is no team scapegoat (everyone screws up so it can't always be the same person responsible for every problem).
168	Commitments are always made with the intention of being met and are almost always met.
169	Coordination drawings are complete and accurate and prepared in sufficient time for review and approval to occur prior to fabrication/installation.
170	Removal of installed work for access issues is non-existent.

171	Lessons learned meeting(s) are scheduled with all participants represented.
172	Stakeholders' working relationships
173	Construction Craft Turnover
174	Labor Strikes
175	Construction Skill Level
176	Potential labor force issues are identified for impact to cost, schedule or design alternatives.
177	Prequalification of bidders has addressed any potential labor agreement issues.
178	Inability to attract and retain craft workers
179	Lack of qualified local contractors expressing interest in project or seeking to joint venture larger work.
180	Competing for craft workers with other projects
181	Compatibility of owner and contractor software (IT)

APPENDIX C

List of 126 Leading Indicators for the First Survey

LI No.	Leading Indicators
1	Cash flow is not considered in project planning
2	Vagueness of responsibility for who will prepare budget estimates and update regularly estimates.
3	Vagueness of the level of detail and what is to be included within any budget estimate.
4	Inappropriate qualifications and assumptions within the budget estimates prepared for each design milestone.
5	Failure to provide budget estimates on time with the level of detail in the format established during the PPP phase
6	Inconsistency in budget estimating of construction and soft costs at each design phase milestone.
7	Inappropriate percentage of contingency to meet the required level of design development.
8	Inconsistency of competitive pricing of overall project or bid packages within qualified bidders.
9	Bidder clarifications and qualifications to bid pricing are not consistent and well defined.
10	Lack of bidder interest and coverage for the type of project.
11	Potential cost exposure issues are not accounted for within the cost control system immediately upon recognition.
12	Cost and schedule disputes resulting from changes are not resolved when identified, rather than deferring until project closeout (Combined LI # 12 and 49)
14	A formal change order process, defining cost and mark-up rates, schedule impact derivation, and dispute resolution procedures, is not in place and adhered to. (Combined LI # 14, 50, 51, 53, 54, and 117)
16	Financial instability of various companies comprising the project team.
17	Unanticipated, abnormal price changes due to external factors.
18	Unexpected, material foreign exchange variances.
19	Failure to prepare resource loaded schedule at outset, include contractor and vendor data or maintain schedule updates in a timely manner with sufficient detail. Failure by project team to make effedctive use of schedule data. (Combined LI # 19 ~25, 27,
26	Inconsistency of bid and award times to meet the schedule during prior project phases.

29	The schedule does not "feel right" in comparison to observable progress on the site.
32	When schedule activities are statused as complete they are only "substantially complete" and not 100% complete.
33	Confidence in schedule's accuracy and validity is doubtful when activity durations change or there are repeated slippages (Combined LI # 33 and 35)
36	Lack of development/decision on detailed scheduling within the PPP phase.
37	Insufficient information to provide legitimate input to the schedule when the schedule input has to be obtained from outside sources.
38	Lack of meeting design milestones and testing future milestones regularly for impact from factors beyond just the progress of the current phase.
39	Bid or begin construction before completion of project buy-out resulting in incomplete scope definition at award (Combined LI # 39, 46, 60, and 61)
40	Vague or nonexistant project objectives or business goals among team or stakeholders (Combined LI # 40, 41, and 42)
43	Excessive contract changes during project execution requested by contractor or owner.(Combined LI # 43 and 57)
44	Change in contracting strategy in the PPP phase.
47	Failure to identify/quantify exclusions from scope by bidders for later procurement.
48	Unrealistic contractor requests for time extensions associated with scope changes.
52	Lack of identification of difference between scope change and design development.
55	Lack of process for issuance of bid addenda and responsibilities not clearly understood by team members.
56	Incomplete bid addenda and inappropriate level of documentation
59	Exclusion of scope(s) of work within all bid packages.
62	Improper recognition of scope gaps in advance of schedule impact.
63	Lack of identification/documentation of start and end dates for all warrantees to all project participants.
64	Large numbers of RFIs with issues not easily addressed.
65	Large numbers of RFI's are being used for change order hunting or backdoor scope changes, not for their legitimate intended purpose.

66	Emergency RFI's (same day/1 day turn around) are occurring at a high level.
67	Late, slow, or inadequate responses to RFI's, questions and changing events by all stakeholders. (Combined LI # 67, 68, 140, and 141)
69	Engineering Deliverables IFC Deviation from Schedule
70	Inappropriate risk management plan, including act of God, war, and terrorism.
73	Unrecognized or unresolved cultural barriers.
74	Design reviews are not clearly defined (the number, the nature, responsibilites of all stakeholders and documentation) and compliance with the rules are not strictly adhered to with respect to timeliness and restrictions as to area of responsibility/exper
79	Increasing level of detailed engineering/design/fabrication errors detected
80	Lack of a job specific, agreed upon definition of "quality."
81	A clearly defined plan does not exist that identifies who has input on quality issues, who collects the information and who has the final say on issues of dispute.
82	Failure to meet quality requirement at the PPP phase to address conflicts/concerns without significant change to the developing documents.
83	Lack of developing a project specific 'Quality in Construction' plan commensurate with the balance of the document set, including project participants roles and responsibilities.
84	Exclusion of project specific QIC plan within bid documents for appropriate flow down information to have plan being enforced during follow-on phase.
85	Failure to follow the requirements of the QIC plan to meet legitimate participation from all parties identified within the plan.
86	By completion of the design phase there are conflicts between the requirements of the project specific QIC plan and individual sections of the project specification/documents.
87	Lack of proper actions and plans for deficiency items following identification for future implementation.
88	Lack of agreement on what items are considered deficiencies.
89	Closeout information is not compiled and submitted for review in a timely manner.
91	Safety Incidents
92	Lack of an analysis of safety/loss prevention considerations by qualified personnel during design reviews.

93	Inactive in safety inspection, awareness and education among all project participants.
94	Delay in resolving confrontations regarding safety issues.
95	Drastic action is often taken with regard to non-compliance issues (fines, dismissals, work stoppages).
97	Lack of decisions regarding big picture issues (a wrap-up insurance program, project medical team, project safety officer, outsourcing of safety compliance inspections, etc.) that should be properly reflected in the procurement packages.
98	Lack of responsibility for preparing a project specific safety plan to be included in the procurement package(s).
99	Failure to develop a project specific safety plan to the same extent as the balance of the design.
100	Project specific safety plan not included in bid documents for appropriate flow down information to allow plan to be enforced during follow-on phase.
101	Failure to follow the requirements of the project specific safety plan, without exception.
102	Failure to maintain project specific safety plan requirements during commissioning phase.
103	High frequency of near misses.
104	Mixed team not properly integrated owner engineers and contract engineers.
105	Hidden agendas within project teams.
106	Inefficient interdisciplinary meeting (less frequent, not productive, and few attendants).
107	Lack of proper documentation of outstanding action items and responsibilities.
108	Failure to expeditiously resolve action items (Combined LI # 108 and 109)
110	Insufficient skilled craft labor staffing due to other projects or inferior wages/work schedules (Combined LI # 110, 173, 175, 178, and 180)
111	Failure to recognize and schedule for interferences between contractors and/or stakeholders (Combined LI # 111 and 170)
112	Lack of manpower, materials, tools & equipment when needed for planned activities.
114	Push to meet market window
116	Unhealthy financial status and/or lack of capability of subcontractors or suppliers to perform work.
118	Delays in submitting, reviewing and approving project closeout deliverables

119	Documentation is not accurate and issued timely manner.
120	Incomplete pre-commissioning performance testing and inspections before commissioning begins.
121	Incorporate scope changes into turnover planning.
122	Low level of maintenance involvement in scope definition. Lack of alignment during execution.
123	Unproven technology
124	Lack of development and implementation of procurement strategy for all services being outsourced including identification of in-house resources to commit to the project.
125	Lack of identification of the commissioning lead and responsibilities are not agreed to or understood.
126	Lack of identification of facility (using agency) personnel with project involvement.
127	Inadequate participation by facilities personnel, through exclusion during the design review and approval cycle, regular project meetings, construction phase inspections and commissioning. (Combined LI # 127, 128, 129, 130, 131, 132, 133, and 134)
135	Lack of identification of attic stock. Inadequate quantities identified or not enough required storage space allowed.
136	Facility engagement beyond core project team
137	Failure to confirm availability of all necessary participants immediately prior to each commissioning event from the facilitator.
138	Lack of identification and documentation of proprietary items.
139	Failure to identify/address missed requirements during design reviews.
142	Inconsistency of providing lien release.
143	Lack of material supplier information.
144	Frequent emergency requests for material substitutions/approval of alternate suppliers materials.
146	Team member's personal problems.
148	Poor team quality whether in - expertise, experience, bench/depth, supervision provisions.
149	Lack of proper experience level of the project manager or team leader.

150	High turnover/lack of stability in project team membership. (Combined LI # 150 and 162)
151	High level of language barriers.
152	Dishonesty, private agendas by one or more stakeholders or poor relations between stakeholders (Combined LI # 152, 153, and 172)
154	Poorly defined approval levels.
155	Poorly defined organizational breakdown structure.
156	Not focusing on resolution of project issues but on the documentation of project problems between parties.
157	Improper communication channels among related parties
158	Determination is not made on the delivery system to be utilized for the project.
159	Determination is not made on what methods of team building (I.e. partnering) if any will be utilized.
161	High Frequency of project personnel's working excessive hours.
163	Inequality between sense of project loyalty/success and company success/loyalty.
164	Team meetings are sporadic, unstructured, unproductive, poorly attended or improperly staffed. (Combined LI # 164, 165, and 166)
168	Commitments are not made with the intention of being met and are almost always not met.
169	Coordination drawings are not complete and accurate nor prepared in sufficient time for review and approval to occur prior to fabrication/installation.
174	Failure to secure project labor agreements prior to commencing work (Combined LI # 174, 176, and 177)
179	Lack of qualified local contractors expressing interest in project or seeking to joint venture on larger work.
181	Lack of compatibility of owner and contractor software (IT).
182	Work done in different time zones
183	Lack of plan or work process which defines when and how to draw down on contingency
184	Team issues/competencies not addressed when identified.
185	Certain project level decisions are made by executives (micro manage)

186	Difficulty integrating schedule between contractors
187	Vendors asked to perform functions outside of their experiences.
188	Use of 'Ironclad' specification.
189	Supplier change project management philosophy/system.
190	Interface with key suppliers is through a salesman
191	Bad Karma
192	Owner failure to plan for changes in operator incentive pay.

APPENDIX D

Rankings of LIs After the First Survey (illustrating how 79 LIs were selected using the 50+10 method - shaded LI numbers were selected)

LI No.	Top 50			Top 10					
	Overall	Contractor	Owner	Cost	Schedule	Quality	Safety	Satisfaction	Benefit Attainment
148	1	13	1	9	5	5	12	5	3
79	2	4	3	9	1	3	19	10	5
43	3	7	2	1	3	25	25	2	2
123	4	2	7	6	7	2	28	20	3
150	5	15	3	14	10	17	16	7	8
40	6	13	6	24	28	11	49	1	1
149	7	10	8	17	20	25	16	16	8
110	8	1	18	29	7	17	12	25	25
114	9	6	14	3	33	22	22	28	8
127	9	34	5	27	33	7	35	7	7
116	11	2	25	17	10	39	24	22	11
80	12	18	10	46	59	1	58	10	5
152	12	11	16	37	33	25	22	10	15
66	14	23	10	3	10	49	42	16	17
74	15	18	15	46	32	15	33	22	11
187	16	9	29	39	41	12	25	28	17
112	17	5	40	29	7	49	16	39	32
67	18	29	12	17	5	45	58	7	55
16	19	34	12	17	33	49	35	16	11
168	19	43	9	46	24	33	35	10	21
64	21	15	31	17	17	33	65	16	42
139	21	18	25	27	24	15	58	47	21

169	23	25	18	29	20	30	35	28	32
108	24	36	16	29	3	39	58	10	90
111	24	7	51	39	24	49	19	22	62
105	26	24	29	46	53	39	33	10	15
122	26	36	18	50	64	7	35	47	17
151	26	28	22	79	53	22	15	28	25
174	26	11	41	17	18	45	40	58	42
14	30	46	22	6	29	84	92	5	25
120	31	25	36	59	43	12	42	58	25
95	32	21	55	68	64	102	5	28	42
69	33	29	38	29	1	74	65	25	90
125	33	46	32	74	43	19	42	39	25
83	35	36	36	88	85	3	42	47	17
10	36	68	25	6	49	70	41	76	42
39	36	29	47	14	29	64	84	39	47
81	36	51	35	88	85	9	84	20	14
184	36	76	22	59	64	39	28	39	32
73	40	59	33	55	49	55	27	47	32
85	40	46	41	68	74	97	1	76	74
91	40	59	33	88	94	5	49	47	21
104	43	21	83	55	49	33	58	28	47
161	43	43	48	59	64	30	19	76	84
156	45	43	55	55	49	33	58	39	55
164	45	59	41	68	59	33	42	28	47
70	47	46	55	50	59	55	30	66	47

94	47	56	48	111	85	84	4	47	62
3	49	109	21	12	59	84	92	39	25
56	49	56	51	24	33	78	84	28	55
92	49	68	38	88	100	49	5	101	62
126	49	56	51	79	64	22	58	58	32
59	53	46	62	29	43	55	84	66	32
65	53	51	60	39	43	78	84	3	84
12	55	36	68	12	53	121	110	3	42
84	55	68	41	99	85	9	74	39	47
93	57	63	55	88	106	84	2	76	74
124	57	29	83	39	41	48	65	76	62
186	57	36	74	59	10	74	30	101	106
9	60	76	41	24	53	55	77	72	55
86	60	36	78	88	94	12	65	58	32
144	62	25	94	59	53	30	65	47	90
11	63	51	74	2	94	103	110	25	21
97	63	73	51	55	81	84	14	76	84
121	63	63	63	79	59	25	42	106	47
179	63	29	90	39	43	74	49	96	47
185	63	82	41	59	43	64	42	58	62
188	63	51	74	29	74	39	74	96	62
107	69	59	68	68	33	55	49	47	90
88	70	17	108	79	64	55	49	28	55
106	70	88	48	74	78	19	92	76	47
100	72	82	60	68	100	107	10	72	90

103	72	51	90	88	94	107	3	76	106
38	74	73	68	74	10	97	84	58	84
62	74	73	68	50	24	70	92	76	99
29	76	82	63	68	10	107	77	66	74
33	76	68	78	74	10	103	103	28	84
4	78	66	88	16	81	113	110	28	32
48	78	82	65	59	29	97	84	39	84
101	80	79	74	111	106	103	7	66	99
102	80	68	86	119	114	97	7	72	74
19	82	67	90	79	18	117	77	47	62
99	83	91	68	79	110	107	9	96	99
119	83	76	86	79	81	29	77	58	106
136	83	126	25	99	94	39	65	76	32
8	86	94	78	50	91	70	77	106	32
82	87	98	78	111	100	19	92	76	55
98	87	102	68	79	110	103	11	76	110
157	87	94	83	79	64	49	49	96	106
1	90	63	99	29	53	117	119	47	74
32	90	88	90	88	33	74	92	101	62
87	92	36	111	88	85	33	84	106	62
158	92	102	78	74	74	55	49	106	99
138	94	121	55	99	91	55	92	76	25
55	95	105	88	59	78	92	92	76	62
137	95	119	65	117	78	64	65	76	74
154	95	79	98	88	64	78	74	76	90

146	98	121	65	122	85	64	30	106	90
17	99	91	96	3	114	123	110	76	62
26	99	94	95	99	20	121	103	72	90
7	101	79	103	9	118	117	119	76	55
5	102	88	105	39	74	123	119	58	99
163	103	100	99	107	100	84	65	96	62
47	104	98	105	54	64	92	103	113	114
155	105	109	99	107	81	78	65	106	110
6	106	114	96	39	110	113	103	101	74
37	107	112	103	111	20	113	110	113	114
52	108	82	118	88	106	92	110	66	99
63	109	102	111	99	122	78	110	66	74
159	109	119	99	107	100	78	49	113	114
2	111	114	105	37	118	125	119	76	74
36	111	112	108	99	33	117	110	112	114
89	111	105	111	125	121	47	119	76	74
118	111	94	116	122	114	55	110	47	110
181	111	109	110	107	94	70	92	101	121
44	116	105	114	59	64	107	103	119	121
189	116	100	116	111	106	64	92	116	99
190	118	91	120	99	91	64	92	123	114
18	119	114	115	17	125	125	119	116	90
143	120	114	119	111	100	84	77	121	123
191	121	82	125	126	118	97	49	123	114
135	122	123	121	117	114	84	126	121	114

183	123	123	122	99	122	113	103	116	123
182	124	105	125	119	110	92	119	123	126
192	125	114	124	122	126	92	77	126	110
142	126	123	123	119	122	107	103	119	123

APPENDIX E

List of Traditional Measures for the Second Survey

TM No.	Traditional Measures
1	Project cost ratios that measure productivity or efficiency versus total installed cost (TIC) were not within acceptable ranges (e.g., labor/material/equipment to TIC; engineering/design cost to TIC).
2	Actual project cash flow reflected a substantial deviation from planned cash flow.
3	The actual hourly wage rate for direct field construction labor and/or engineering/design staff was much higher than the estimated hourly wage rate.
4	Committed cost and actual expenditures have exceeded projections based on the project budget and plan.
6	The dollar contingency used was higher than planned at key reporting milestones (e.g., start of construction).
7	Estimate basis, assumptions, and documentation were insufficient to produce a reliable estimate for controlling project costs.
8	The project had a substantial level of outstanding accounts payable or accounts receivable.
9	The project's actual overtime hours and costs have exceeded planned overtime hours and costs.
10	Actual bulk material quantities were greater than estimated or forecasted total bulk material quantities (e.g., steel, straight run pipe, electrical wire and cable).
11	The project team has not consistently used look ahead schedules for short range planning.
12	Floats for project activities have been used at an increasingly high rate.
13	The project frequently missed key milestone dates.
15	The actual percent completed divided by the planned percent complete was less than 1.0 over several reporting periods.
16	The project had a low percent engineering/design completion at the start of construction.
19	The receipt of actual vendor drawing was later than the planned receipt of vendor drawing.
22	Actual release of Approved for Construction (AFC) drawings was later than planned release of AFC drawings.
24	Actual schedule activities were behind planned scheduled activities over several reporting periods.
25	Project performance as determined by earned value (percent complete times budget) divided by actual expenditures was less than 1.0 over several reporting periods.

26	Cost forecasting and productivity analysis have not been performed on a timely basis.
27	Actual productivity was less than planned productivity based on the current budget (total project or by individual discipline for either engineering/design or construction labor).
28	Forecasts-to-complete based on actual project experience combined with actual expenditures to date have consistently showed overruns in engineering/design, procurement, and/or construction budgets (total project or discipline or by project phase).
29	Trends documenting potential overruns were not identified in a timely manner.
30	Project change management process has not identified potential scope changes in a timely manner for decision-making.
31	The number of actual change orders approved and number of potential change orders in process have increased beyond allowable levels for scope change.
32	Change orders were not approved within a reasonable time period.
33	The project had an above normal level of rework hours and costs when compared to target levels of rework included in the total budget.
37	Project quality control results reflected high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.
39	Actual safety measures were higher than target safety measures in one or more of the following areas: recordable incident rates; Days Away or Restricted Time (DART); first aid cases; incidents and subcontractor incidents; and safety program compliance, including drug test results.

APPENDIX F

List of 87 Leading Indicators for the Second Survey

LI No.	Leading Indicators
3	The level of detail and the scope covered in the budget estimate are not clear.
7	The project contingency is inconsistent with the level of design development.
9	Bidder clarifications and qualifications related to bid pricing are inconsistent and not well defined.
10	The project lacks bidders that are interested in the project and fit the type of project for which they are bidding.
11	Potential cost exposure issues are not accounted for within the cost control system immediately upon recognition.
12	Cost and schedule disputes resulting from changes are not resolved when identified and resolution is deferred until project closeout.
14	The project is not following an appropriate change management that includes defining cost and mark-up rates, evaluating schedule impact, and/or initiating dispute resolution procedures.
16	Some project participant companies are not financially stable.
17	The project is experiencing unanticipated, abnormal price changes due to external factors.
29	The schedule does not "feel right" in comparison to observable progress on the site.
33	The project team is losing confidence in the accuracy and validity of the schedule due to constantly changing activity durations and repeated slippages from one reporting period to the next.
38	Design milestones are not met and achieving future phases milestones are not confirmed in relation to the impact of factors beyond information provided in current progress and status reports.
39	Construction is bid or commences before completion of project design resulting in an incomplete scope definition at time of award.
40	Business goals, project objectives, and critical success factors are vague and/or inconsistent relative to project team and key stakeholder understanding.
43	Owner and/or contractor is requesting an excessive number of contract changes during project execution (detailed design, procurement, construction, and start up).
56	The bid specifications, documentation, and addenda covered in the pre-bid meeting are incomplete.
59	Project scope items are omitted from bid packages.

64	The project is experiencing an increasing number of Requests for Information focusing on issues that are not easily addressed.
65	A substantial number of Requests for Information are being used improperly such as for change order hunting or for backdoor scope changes.
66	The frequency of emergency Requests for Information (same day or one day turn around time) is increasing substantially.
67	The project teams response to Requests for Information, questions, and changing events that can significantly impact project results is slow, inadequate or very late.
69	Engineering/design deliverables are not completed on time as planned per the project schedule.
70	The project risk management plan (identification, assessment, and mitigation) does not adequately cover project uncertainties, including acts of God, war, and/or terrorism.
73	The project is experiencing issues related to business/organizational barriers that are not being recognized or are not being resolved.
74	Design review requirements are not clearly defined (e.g., the number of reviews, the nature of the reviews, the level of documentation necessary, and the responsibilities of reviewers) and compliance with the requirements are not strictly adhered to with respect to timeliness and discipline responsibility for the reviews.
79	The project is experiencing a high level of detailed engineering/design/specification errors and changes.
80	The project lacks a project specific, agreed upon definition of quality.
81	The project lacks a clearly defined plan that identifies who has input on quality issues, collects information and/or has the final decision on issues under dispute.
83	A project specific quality plan for construction is not completely developed that is consistent with the contract documents, including plans and specifications, and project participant roles and responsibilities.
84	A project specific quality plan for construction is not included in the bid documents with appropriate instruction for implementation during project construction.
85	The project fails to follow the quality plan for construction in relation to the roles and requirements of those who are responsible for that plan.
86	There are conflicts between the quality plan for construction in design documents and the specific requirements in the specifications and drawings for each design discipline.
87	The project team fails to take proper action when deficiency items are identified to reduce or eliminate their future impact.
88	The project team lacks agreement on what items are considered deficiencies.

91	The project is experiencing a high level of safety incidents.
92	Design reviews fail to include qualified personnel that can analyze safety and loss prevention features of plans and specifications.
93	Project team personnel lack involvement in safety inspections, awareness of safety issues, and education in safety practices.
94	Potential safety related problems are not resolved in a timely manner.
95	Drastic actions (e.g., fines, dismissals, work stoppages) are often needed to address non-compliance in safety practices.
99	The project safety plan is not developed to the same level of detail as the design plan.
100	Contractors are not including a proposed project safety plan in their bid documents.
101	The project is not following the requirements of a project specific safety plan during construction.
102	The project is failing to follow the requirements of a project specific safety plan during the startup and commissioning phase.
103	The project is experiencing a high frequency of near misses.
104	Owner and contractor project personnel are not properly integrated into the project team.
105	Hidden agendas are apparent within project teams.
106	Interdisciplinary team meetings are not effective (not productive, missing key personnel, and held infrequently).
108	The project team does not resolve action items expeditiously.
110	The project lacks sufficient skilled craft and is experiencing high craft turnover due to competition from other projects, low wages, and shorter work schedules.
111	The project schedule fails to recognize potential interferences between contractors and key stakeholders.
112	The project lacks sufficient manpower, materials, small tools and construction equipment to adequately support planned activities.
114	The push to meet a market window is not adequately addressed in project execution plans and project decision-making processes.
116	Project progress is slipping because of unhealthy financial status and/or lack of capability of subcontractors or suppliers who are performing the work.

120	Pre-commissioning performance tests and inspections are not complete prior to commissioning/startup activities.
122	The level of maintenance personnel involvement in detailed design is low and maintenance personnel are not aligned with other project team personnel with respect to maintenance issues for the facility.
123	The project is using new technology or construction practices that are unproven in commercial use.
124	The project procurement strategy is lacking development and implementation of all services being outsourced, including the identification of in-house resources committed to the project.
125	The commissioning activity is lacking clear definition of who leads and is responsible for this activity.
126	The project team is failing to clearly identify facility (agency or operating) personnel with project involvement.
127	Facility personnel are not adequately participating in key project execution activities such as design reviews and approvals, regular meetings, construction inspections, and commissioning.
136	Facility engagement is not being considered beyond involvement of the core project team.
139	The project team is failing to identify and/or address missing requirements during design reviews.
144	The project is frequently requesting material substitutions or approval of alternate supplier's materials on an emergency basis.
148	The project team is lacking in the necessary expertise, experience, breadth and depth to successfully execute the project.
149	The project manager (or team leader) is lacking in the required level of experience and skills.
150	The project team is experiencing a high turnover rate and instability in team membership.
151	The project team is experiencing communication difficulties due to language barriers.
152	Key project stakeholder(s) is (are) exhibiting poor relationships and pursuing private agendas.
156	The project team is not focusing on resolving issues only on documenting problems between project participants.
161	Project team personnel are frequently working excessive hours.
164	Team meetings are increasingly sporadic, unstructured, unproductive, poorly attended, and/or improperly staffed.

168	Commitments are increasingly not made with the intention of being met and are almost always not met.
169	Coordination drawings are frequently not complete and accurate nor prepared in sufficient time for review prior to fabrication/installation.
174	The project is failing to secure project labor agreements prior to commencing work.
179	The project is having difficulties finding qualified local contractors or contractors who will joint venture on larger projects.
184	Team competencies and other issues impacting performance are not being addressed as they are identified.
185	Executives are making an increasing number of decisions for the project (micro management).
186	The project is experiencing difficulties in integrating schedules between participants.
187	The project is asking vendors to perform functions outside their areas of expertise and experience.
193	Prefabrication delivery priorities are not being defined clearly in bid inquiry documents in support of geographic area sequencing in relation to the project site.
194	Field resources are mobilizing prior to engineering/design being ready to support construction.
195	Drawings are being released *Approved for Construction* with an excessive number of “holds.”
196	The project filing system is failing to furnish information in a timely manner due to lack of proper organization.
197	Hazard and Operability (HAZOP) plan is late or is experiencing an excessive number of operational/support items that are not complete during the design phase.
198	The project team is not being encouraged to be realistic and truthful when project circumstances are unfavorable.
199	The project manager is not using lessons learned from previous and similar projects.
200	The PDRI (project definition rating index) score is not decreasing early in detailed design as the design and project execution plan are being prepared.

APPENDIX G

Rankings of LIs After the Second Survey (illustrating how 53 LIs were selected using the 25+10 method - shaded LI numbers were selected)

LI No.	Top25			Top 10				
	Overall	Contractor	Owner	Cost	Schedule	Quality	Safety	Satisfaction
148	1	1	1	11	1	4	13	2
110	2	2	3	16	7	13	10	15
79	3	4	5	9	12	10	33	5
149	3	6	2	13	13	23	15	3
116	5	3	10	18	6	23	16	9
10	6	10	6	12	29	18	27	15
150	7	7	7	27	13	21	23	7
123	8	5	7	20	19	11	17	40
112	9	10	20	27	5	43	19	32
16	10	7	20	20	25	30	23	21
187	11	23	7	45	34	6	19	62
104	12	9	27	32	40	21	17	19
95	13	23	15	54	55	73	3	32
40	14	28	12	20	43	16	65	1
91	14	10	27	60	68	70	1	21
198	16	10	22	32	40	30	27	7
43	17	19	24	9	10	64	59	10
74	17	30	14	36	19	18	45	12
12	19	16	46	1	36	55	69	5
114	19	68	4	20	29	42	31	19
3	21	51	10	1	29	56	59	15
152	21	10	48	32	40	36	33	3
185	23	44	18	30	34	34	33	21
80	24	16	47	52	61	1	53	15
59	25	18	35	6	18	46	79	32

14	26	20	36	3	23	60	79	12
168	26	27	24	41	15	46	37	11
197	28	39	15	65	62	20	9	79
81	29	20	40	54	52	2	65	27
69	30	26	40	20	1	53	69	51
120	31	59	15	78	29	13	37	12
92	32	46	23	62	76	38	8	74
94	32	39	26	75	66	75	6	51
139	32	59	12	20	43	23	50	32
39	35	10	60	13	25	51	59	32
169	36	30	29	41	15	37	42	58
9	37	53	33	5	43	51	73	32
199	38	37	37	45	58	28	23	58
67	39	30	57	26	11	56	79	27
174	40	63	31	32	29	60	29	67
111	41	48	44	41	19	66	33	40
156	42	30	53	45	43	38	42	32
195	43	35	59	30	15	56	55	58
103	44	39	55	84	81	77	3	27
127	44	69	29	65	60	11	45	27
164	44	46	48	70	62	28	29	21
179	44	59	37	45	38	49	23	79
87	48	28	57	45	58	16	59	45
125	48	59	37	73	43	33	31	45
186	48	63	40	54	8	66	50	40
83	51	20	70	62	68	4	47	56
93	52	69	33	82	84	62	3	74

101	52	23	72	81	82	83	2	51
105	52	39	66	39	55	46	37	32
56	55	65	40	16	36	43	77	74
64	55	30	70	36	25	41	82	45
151	55	49	48	78	66	30	19	40
85	58	44	55	70	68	3	55	51
144	58	49	60	52	43	23	59	62
106	60	65	48	62	43	49	37	21
108	60	53	60	41	19	62	55	45
184	62	83	18	72	62	34	19	62
66	63	35	80	27	25	70	65	51
102	64	53	65	85	84	70	7	27
84	65	53	60	60	78	6	47	67
65	66	38	82	15	38	66	84	40
161	66	39	72	73	72	43	14	74
122	68	73	48	78	79	8	41	45
29	69	51	77	54	8	79	50	70
33	69	53	74	54	1	81	69	70
86	71	53	69	65	73	8	73	58
38	72	65	74	39	4	85	83	62
124	73	75	53	36	50	56	65	70
200	73	84	31	45	51	53	44	81
73	75	81	44	45	52	64	73	21
88	76	72	68	75	73	13	77	56
126	77	79	66	75	55	38	73	67
11	78	78	79	6	76	81	86	45
193	79	75	78	65	23	73	55	83

194	79	74	80	18	62	77	47	83
7	81	80	74	4	82	79	84	62
136	82	85	60	82	79	23	53	70
17	83	77	84	6	75	84	86	74
196	84	71	86	65	52	69	69	81
70	85	81	85	59	68	76	59	83
99	86	86	87	87	87	85	11	86
100	87	87	83	85	86	87	11	87

APPENDIX H

List of 67 Leading Indicators for the Third Survey

LI No.	Leading Indicators
3	The level of detail and the scope covered in the budget estimate are not clear.
9	Bidder clarifications and qualifications related to bid pricing are inconsistent and not well defined.
10	The project lacks bidders that are interested in the project and fit the type of project for which they are bidding.
11	Potential cost exposure issues are not accounted for within the cost control system immediately upon recognition.
12	Cost and schedule disputes resulting from changes are not being resolved when identified and resolution is being deferred until project closeout.
14	The project change management process is not identifying potential scope changes in a timely manner for decision making (includes defining cost and mark-up rates, evaluating schedule impact, obtaining appropriate approval authority, and initiating disputes.
16	Some project participant companies appear to be financially unstable.
17	The project is experiencing unanticipated, abnormal price changes due to external factors.
29	The schedule does not "feel right" in comparison to observable progress on the site.
33	The project team is losing confidence in the accuracy and validity of the schedule due to constantly changing activity durations and repeated slippages from one reporting period to the next.
38	Design milestones are not being met and are consequently jeopardizing future project milestones.
39	Construction is bid or commences before adequate completion of project design, including discipline design packages, resulting in an incomplete scope definition at time of award/start of construction.
40	Business goals, project objectives and priorities, and critical success factors are not being consistently used by project team members and key stakeholders to guide decisions.
43	Owner and/or contractor is requesting an excessive number of contract changes during project execution (detailed design, procurement, construction, and start up).
59	Significant project scope items are omitted from bid packages.
67	The project team's response to Requests for Information, questions, and changing events that can significantly impact the project results is slow, inadequate, or incomplete.

69	Engineering/design deliverables are not being completed on time as planned per the project schedule.
74	Design review requirements are not clearly defined (e.g., the number and nature of reviews, the level of necessary documentation, and the responsibilities of reviewers) and compliance with the requirements is not strictly adhered to with respect to timeli
79	The project is experiencing a high level of engineering/design/specification errors and changes.
81	The project does not identify who has input on quality issues, collects information and/or has the final decision on issues under dispute.
83	A project specific quality plan is not consistent with the contract documents (plans and specifications).
84	A project specific quality plan for construction is not included in the bid documents with appropriate instructions for implementation during construction.
85	The project fails to follow the quality plan for construction in relation to the roles and requirements of those who are responsible for that plan.
91	The project is experiencing a high level of safety incidents.
92	Design reviews fail to include qualified personnel who can analyze safety and loss prevention features of plans and specifications.
93	Project team personnel lack involvement in safety inspections, awareness of safety issues, and education in safety practices.
94	Potential safety related problems are not being resolved in a timely manner.
95	Non-compliance in safety practices is resulting in an increased level of drastic actions (e.g., fines, dismissals, work stoppages, etc.).
101	The project is not following the requirements of a project specific safety plan during construction.
103	The project is experiencing a high frequency of near misses.
104	Owner and contractor project personnel are not being properly integrated into the project team.
110	The project lacks sufficient skilled craft and is experiencing high craft turnover due to competition from other projects, low wages, and shorter work schedules.
112	The project lacks sufficient manpower, materials, small tools, and construction equipment to adequately support planned construction activities.

122	The level of maintenance personnel involvement in detailed design is low and maintenance personnel lack alignment with other project team personnel with respect to maintenance issues for the facility.
123	The project is using new technology or construction practices that are unproven in commercial use.
139	The project team is failing to identify and/or address missing requirements during design reviews.
148	The project team is lacking in the necessary expertise, experience, breadth, and depth to successfully execute the project.
149	The project manager (or team leader) is lacking in the required level of experience and skills.
150	The project team is experiencing a high turnover rate and instability in team membership.
152	Key project stakeholder(s) is (are) exhibiting poor relationships and pursuing private agenda.
168	Commitments are increasingly not made with the intention of being met and are almost always not met.
184	Team competencies and other issues impacting performance are not being addressed when identified.
185	Executives are making an increasing number of decisions for the project (micro management).
186	The project is experiencing difficulties in integrating schedules between project participants.
187	The project is frequently asking vendors, suppliers, and service providers to perform functions outside their areas of expertise and experience.
197	Hazard and Operability (HAZOP) plan is late and/or is experiencing an excessive number of operational/support items that are not complete during the design phase.
198	The project team is not being realistic and truthful when project circumstances are unfavorable.
202	Actual project cash flow is reflecting a substantial deviation from planned cash flow.
203	Actual productivity and hourly wage rates are showing negative deviations from planned productivity and hourly wage rates (total project or by individual discipline for either engineering/design or construction labor).
206	The dollar contingency is decreasing at a rate higher than the amount of remaining work to complete.
208	The project is incurring a substantial level of outstanding accounts payable or accounts receivable.

210	Actual bulk material quantities are greater than estimated or forecasted total bulk material quantities (e.g., steel, straight run pipe, electrical wire and cable).
211	The project team is not using short range (e.g., two weeks or one month) look ahead schedules to plan the work on a weekly basis.
212	Float for project activities is being used up at an increasingly high rate.
213	The project is missing key milestone dates.
216	The project percent engineering/design completion is low at the start of construction.
219	The receipt of actual vendor drawings is slipping beyond the planned date for receipt of vendor drawings.
224	Actual schedule activities are lagging behind planned scheduled activities over several reporting periods.
228	Forecasts-to-complete based on actual project experience combined with actual commitments and expenditures are consistently projecting overruns in engineering/design, procurement, and/or construction budgets (by total project, by discipline and/or by proj
232	Change orders are not approved within a reasonable time period.
233	The project is experiencing an above normal level of rework hours and costs when compared to target levels of rework included in the total budget.
237	Project quality control results are reflecting high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.
239	Actual safety measures are higher than target safety measures in one or more of the following areas: recordable incident rates; Days Away or Restricted Time (DART); first aid cases; incidents and subcontractor incidents; and safety program compliance, inc
301	The project is experiencing difficulties due to the lack of understanding cultural differences.
302	Material and/or equipment prices are increasing rapidly for certain types of materials/equipment that represent a high percent of the project cost.
303	The client and/or upper management is frequently making unreasonable requests (includes setting unrealistic goals).
304	Identification of change is limited to a few key staff (there is no project wide involvement in change management).

APPENDIX I

Protocol Used for the Third Ssurvey

BACKGROUND

CII Research Team 220, Leading Indicators to Project Outcome, is conducting research through Texas A&M University. The primary purpose of this research is to identify a potential best practice for conducting project reviews during the course of the project. The status of a project is periodically evaluated by traditional methods or standard practices or referred to as "Traditional Measures." These methods have indicators that are measured to provide hard data on a project's current status and progress.

However, these Traditional Measures may not adequately identify project problems that may exist. It may be that current methods lack the ability to provide real time indications of emerging problems that impact project outcomes in a timely manner. Therefore, if a new tool is developed to help meet this need that can measure whether or not a project is "on-the-right-track," the probability of project success can be enhanced. The key deliverable of the research team will be "Leading Indicators" for successful projects that can be measured in real time to predict project outcomes and an easy-to-use tool to measure the level of "on-the-right-track" for projects.

More than two hundred Leading Indicators have been identified by the research team members and finally narrowed down to sixty seven indicators through a screening process. These selected Leading Indicators will be evaluated in terms of their potential negative impact on the five Project Outcomes described below. Therefore, a thorough understanding of the definitions of Leading Indicators and five Project Outcomes is critical prior to completing this questionnaire.

KEY DEFINITIONS

LEADING INDICATORS

Leading Indicators are fundamental project characteristics and/or events that reflect or predict project health. Revealed in a timely manner, these indicators allow for proactive management to influence project outcomes.

PROJECT OUTCOMES

Cost

Cost performance is viewed in terms of overall actual final cost verses the established project budget. Secondary cost outcomes can include cost / cash flow deviation (compliance with spending plans), cost efficiency, (how efficiently an asset is design and constructed verses similar facilities in industry), and consumption of contingency or reserves.

Schedule

Schedule performance is viewed in terms of overall actual final duration verses the planned project duration. Secondary schedule performance can include outage duration performances and overall engineering and construction cycle time (for certain fast track projects).

Quality / Operability

Quality and Operability are outcomes that are based upon a facility being capable of operating per its intended function and that the quality of the facility and construction craftsmanship matches the intended asset life. (For example, if we build a facility that is intended to make 100 widgets a day, the facility should be capable of making 100 widgets a day)

Safety

Safety as an outcome is a combination of the construction safety during the course of the project and the overall safety considerations of the new facility that will enable it to operate safely over its production life-cycle. Construction safety involves the accidents to personnel in the battery limits of the construction zone and is general viewed in terms of recordable or Days Away or Restricted Time (DART) cases. Facility safety is of a more long-term outcome and is based upon the facility having the equipment, protections, and or warning/safety devices, safe job procedures, energy control procedures etc. required for the facility to operate in a safe manner.

Stakeholder Satisfaction

Stakeholder satisfaction is the overall pride, satisfaction, contentment and / or happiness that the stakeholders have with the outcome of the project. It is somewhat a measure of the potential for future repeat business.

LIMITATIONS

The Leading Indicators in this questionnaire are intended to be applied during project execution that includes the following phases: detailed engineering/design, procurement, construction, and start-up.

LIMITATIONS

The Leading Indicators in this questionnaire are intended to be applied during project execution that includes the following phases: detailed engineering/design, procurement, construction, and start-up.

This questionnaire does not address what to measure concerning a Leading Indicator.

QUESTIONNAIRE

This questionnaire is designed to evaluate Leading Indicators in terms of their potential negative impact on each of the five Project Outcomes. Your input will be used to rank order the sixty seven Leading Indicators.

The questionnaire consists of four sections. In Section I, you are requested to provide contact information. In Section II, specific instructions are provided to assist you in completing the survey with an example. Section III is the main questionnaire that you should complete. Finally, Section IV is provided for additional comments or suggestions for the research.

This questionnaire has been pre-tested and it was observed that it takes up to 60 minutes to review and respond to the questions.

Your participation is purely voluntary. If you decide to participate but are uncomfortable providing your name, you may leave th space for "Name" blank. This questionnaire will remain confidential under Level Two (2) of the CII Data Confidentiality Guidelines. A Level Two (2) Confidentiality designation means that company and project information is removed for publication, and that access to raw data is restricted to the researcher and/or the CII Director with minimum additional staff processing on a need-to-know basis.

We appreciate your support of this request and look forward to receiving your response.

If you have questions concerning the content of the questionnaire, please contact Dr. Stuart D. Anderson at the telephone numbe or email address shown below.

Dr. Stuart D. Anderson
Department of Civil Engineering **TEL: (979) 845-2407**
3136 TAMU **FAX: (979) 845-6554**
Texas A&M University **EMAIL: s-anderson5@tamu.edu**
College Station, TX 77843-3136

Please complete this electronic questionnaire and return it via e-mail to Jiwon Choi, a research assistant, at the e-mail address shown below or you can print, complete, and mail or fax it back to the address or fax number shown below by **Friday, July 8, 2005**, or earlier, if possible.

Please make sure save the Excel file before you send it.

RETURN TO: z1choi@tamu.edu

If you have any problems returning the questionnaire to the above address, please return it to z1choi@gmail.com

To complete the questionnaire properly, you need to have Microsoft® Office Excel 97 or later version. This questionnaire is best viewed at screen resolution 1024 x 768 with zoom 100%. If you have any questions, please contact Jiwon Choi at the telephone number or email address shown below.

Jiwon Choi
Research Assistant
Department of Civil Engineering **TEL: (979) 845-6023**
3136 TAMU **FAX: (979) 845-6554**
Texas A&M University **EMAIL: z1choi@tamu.edu**
College Station, TX 77843-3136

EVALUATION OF LEADING INDICATORS

SECTION I: RESPONDENT INFORMATION

Questionnaire completed by:			
Name (Optional):		Company:	
Position:		Industry Experience (years):	
Phone:		Email:	
Characteristic of Company:	○ Owner ○ Contractor ○ Engineer/Designer ○ Contractor/Engineer/Designer		

SECTION II: SPECIFIC INSTRUCTIONS AND EXAMPLE

A list of Leading Indicators each of which has a table listing five project outcomes is presented below. Please evaluate each Leading Indicator in terms of their potential **NEGATIVE IMPACT** on the five Project Outcomes and mark one of the six blank circles below based on your perception of the potential negative impact. Please follow the steps below.

1. As the first step, make sure that you read and understand the key definitions of Leading Indicators and each of the five Project Outcomes all of which are written in the introduction (see Introduction Tab). This provides the basis for completing this questionnaire.

2. In Section III, you are requested evaluate the Leading Indicators in terms of their potential **NEGATIVE IMPACT** on the five Project Outcomes: Cost, Schedule, Quality/Operability, Safety, and Stakeholder Satisfaction.

   If you think that a Leading Indicator has:

   <u>very high</u> negative impact, then mark in the circle under the "**VERY HIGH**" column for all applicable Project Outcomes,
   <u>high</u> negative impact, then mark in the circle under the "**HIGH**" column for all applicable Project Outcomes,
   <u>moderate</u> negative impact, then mark in the circle under the "**MODERATE**" column for all applicable Project Outcomes,
   <u>low</u> negative impact, then mark in the circle under the "**LOW**" column for all applicable Project Outcomes,
   <u>very low</u> negative impact, then mark in the circle under the "**VERY LOW**" column for all applicable Project Outcomes, or
   <u>no</u> negative impact, then mark in the circle under the "**NO IMPACT**" column for all applicable Project Outcomes.

   If you have any comments or suggestions for a specific Leading Indicator, please type or write in the provided box under each evaluation table.

3. Review the example below before starting.

4. In Section VI, you can suggest any additional Leading Indicators that you think necessary for the research and also you are requested to provide comments or suggestions for the research.

5. While you are writing in a box, you cannot mark in the circle. Therefore, make sure the cursor is not in the box when you want to mark in a circle.

The project is experiencing a high level of safety incidents.

EXAMPLE

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	◉	○	○
SCHEDULE	○	○	◉	○	○	○
QUALITY / OPERABILITY	○	○	◉	○	○	○
SAFETY	○	○	○	○	○	◉
STAKEHOLDER SATISFACTION	○	○	○	○	◉	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR: Any comments or suggestions would be appreciated!

START FROM HERE

SECTION III: EVALUATION OF LEADING INDICATORS

The level of detail and the scope covered in the budget estimate are not clear.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project is experiencing an above normal level of rework hours and costs when compared to target levels of rework included in the total budget.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Construction is bid or commences before adequate completion of project design, including discipline design packages, resulting in an incomplete scope definition at time of award/start of construction.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project lacks bidders that are interested in the project and fit the type of project and location for which they are bidding.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

A project specific quality plan for construction is not included in the bid documents with appropriate instructions for implementation during construction.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The dollar contingency is decreasing at a rate higher than the amount of remaining work to complete.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project is experiencing unanticipated, abnormal price changes due to external factors.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The schedule does not "feel right" in comparison to observable progress on the site.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Business goals, project objectives and priorities, and critical success factors are not being consistently used by project team members and key stakeholders to guide decisions.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Bidder clarifications and qualifications related to bid pricing are inconsistent and not well defined.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project is experiencing a high level of safety incidents.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project team is losing confidence in the accuracy and validity of the schedule due to constantly changing activity durations and repeated slippages from one reporting period to the next.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Design review requirements are not clearly defined (e.g., the number and nature of reviews, the level of necessary documentation, and the responsibilities of reviewers) and compliance with the requirements is not strictly adhered to with respect to timeliness and discipline responsibility for the reviews.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Potential cost exposure issues are not accounted for within the cost control system immediately upon recognition.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project does not identify who has input on quality issues, collects information, and/or has the final decision on issues under dispute.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Owner and/or contractor is requesting an excessive number of contract changes during project execution (detailed design, procurement, construction, and start up).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project team is experiencing a high turnover rate and instability in team membership.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Design reviews fail to include qualified personnel who can analyze safety and loss prevention features of plans and specifications.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project team's response to Requests for Information, questions, and changing events that can significantly impact the project results is slow, inadequate, or incomplete.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project is using new technology or construction practices that are unproven in commercial use.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Design milestones are not being met, and are consequently, jeopardizing future project milestones.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project manager (or team leader) is lacking in the required level of experience and skills.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Actual safety performance measures are higher than target safety measures in one or more of the following areas: recordable incident rates; Days Away or Restricted Time (DART); first aid cases; incidents and subcontractor incidents; and safety program compliance, including drug test results.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project change management process is not identifying potential scope changes in a timely manner for decision making (includes defining cost and mark-up rates, evaluating schedule impact, obtaining appropriate approval authority, and initiating dispute resolution procedures).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

A project specific quality plan is not consistent with the contract documents (plans and specifications).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project percent engineering/design completion is lower than planned at the start of construction.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Team competencies and other issues impacting performance are not being addressed when identified.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Project team personnel lack involvement in safety inspections, awareness of safety issues, and education in safety practices.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project team is failing to identify and/or address missing requirements during design reviews.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Engineering/design deliverables are not being completed on time as planned per the project schedule.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Forecasts-to-complete based on actual project experience combined with actual commitments and expenditures are consistently projecting overruns in engineering/design, procurement, and/or construction budgets (by total project, by discipline and/or by project phase).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project is experiencing a high level of engineering/design/specification errors and changes.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Actual schedule activities are lagging behind planned scheduled activities over several reporting periods.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Project quality control results are reflecting high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Potential safety related problems are not being resolved in a timely manner.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Identification of change is limited to a few key staff (there is no project wide involvement in change management).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project is incurring a substantial level of outstanding accounts payable or accounts receivable.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Owner and contractor project personnel are not being properly integrated into the project team.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project lacks sufficient crews, materials, small tools, and construction equipment to adequately support planned construction activities.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Key project stakeholder(s) is (are) exhibiting poor relationships and pursuing private agenda.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project team is not using short range (e.g., two weeks or one month) look ahead schedules to plan the work on a weekly basis.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Significant project scope items are omitted from bid packages.						
OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project fails to follow the quality plan in relation to the roles and requirements of those who are responsible for that plan.						
OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project team personnel are lacking in the necessary expertise, experience, breadth, and depth to successfully execute the project.						
OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Executives are making an increasing number of decisions for the project (micro management).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Worker non-compliance in safety practices is resulting in an increased level of drastic actions (e.g., fines, dismissals, work stoppages, etc.).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project is experiencing difficulties in integrating schedules between project participants.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Commitments are increasingly not made with the intention of being met and are almost always not met.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The level of maintenance personnel involvement in detailed design is low and maintenance personnel lack alignment with other project team personnel with respect to maintenance issues for the facility.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project is not following the requirements of a project specific safety plan during construction.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Some project participant companies appear to be financially unstable.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project team is not being realistic and truthful when project circumstances are unfavorable.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The receipt of actual vendor drawings is slipping beyond the planned date for receipt of vendor drawings.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Actual productivity and hourly wage rates are showing negative deviations from planned productivity and hourly wage rates (total project or by individual discipline for either engineering/design or construction labor).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

The project is frequently asking vendors, suppliers, and service providers to perform functions outside their areas of expertise and experience.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Cost and schedule disputes resulting from changes are not being resolved when identified, and resolution is being deferred until project closeout.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○

COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:

Float for project activities is being used up at an increasingly high rate.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project is experiencing a high frequency of near misses.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Actual project cash flow is reflecting a substantial deviation from planned cash flow.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project lacks sufficient skilled craft and is experiencing high craft turnover due to competition from other projects, low wages, and shorter work schedules.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Actual bulk material quantities are greater than estimated or forecasted bulk material quantities (e.g., steel, straight run pipe, electrical wire and cable).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project is missing key milestone dates.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Hazard and Operability (HAZOP) plan is late and/or is experiencing an excessive number of operational/support items that are not complete during the design phase.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Change orders are not approved within a reasonable time period.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The project is experiencing difficulties due to the lack of understanding cultural differences.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

Material and/or equipment prices are increasing rapidly for certain types of materials/equipment that represent a high percent of the project cost.

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

The client and/or upper management is frequently making unreasonable requests (includes setting unrealistic goals).

OUTCOMES \ NEGATIVE IMPACT	NO IMPACT	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
COST	○	○	○	○	○	○
SCHEDULE	○	○	○	○	○	○
QUALITY / OPERABILITY	○	○	○	○	○	○
SAFETY	○	○	○	○	○	○
STAKEHOLDER SATISFACTION	○	○	○	○	○	○
COMMENTS OR SUGGESTIONS ON THIS LEADING INDICATOR:						

SECTION IV: COMMENTS OR SUGGESTIONS

Please suggest any additional Leading Indicators that you have in mind but not in the list or give any comments or suggestions for the research in the box below. (PLEASE SAVE AFTER YOU FINISH THIS SECTION)

THANK YOU!

DO NOT FORGET TO SAVE!

APPENDIX J

Rankings of LIs After the Third Survey (illustrating how 49 LIs were selected using the 25+10 method - shaded LI numbers were selected)

LI No.	Top 25			Top 10				
	Overall	Contractor	Owner	Cost	Schedule	Quality	Safety	Satisfaction
148	1	1	1	9	10	7	9	1
110	2	2	2	18	11	9	10	16
95	3	3	13	42	31	34	5	19
198	4	6	5	20	20	21	17	2
112	5	4	17	32	4	23	12	27
149	6	7	8	23	21	18	14	15
79	7	4	19	7	17	10	36	8
59	8	11	7	3	8	20	34	11
91	9	8	12	47	47	48	1	5
139	10	16	4	16	26	8	28	25
43	11	9	28	4	13	31	31	14
150	12	14	13	36	29	14	18	23
40	13	15	15	25	34	13	26	6
168	14	12	26	28	8	29	24	9
237	15	9	33	30	16	4	42	26
187	16	19	9	43	46	4	14	49
92	17	18	15	53	55	19	8	29
123	18	23	9	32	39	14	13	46
197	19	25	11	49	42	16	11	38
67	20	13	26	17	14	21	30	27
303	21	32	3	32	28	29	19	12
14	22	21	21	5	14	37	52	9
239	23	19	23	54	52	50	4	19

16	24	29	18	28	24	25	21	32
228	25	17	36	1	29	43	44	3
233	26	22	32	12	22	23	37	39
3	27	37	5	6	31	32	42	13
152	28	26	29	39	39	27	25	4
184	29	34	22	46	41	17	20	41
101	29	23	41	64	57	45	2	24
38	31	27	33	22	2	44	47	17
94	32	30	31	63	59	49	3	21
33	33	27	38	35	1	51	32	17
10	34	30	35	19	37	27	22	54
74	35	32	39	43	35	12	37	36
122	36	44	24	59	54	3	27	33
39	37	43	29	10	24	38	41	54
12	38	35	49	7	26	51	58	7
81	39	37	42	51	51	6	49	29
104	40	47	25	54	47	26	22	35
186	40	44	40	48	12	47	29	36
93	42	37	46	66	64	42	5	44
301	43	54	20	59	50	32	14	50
213	43	40	47	36	5	59	47	22
69	45	36	54	27	6	46	57	39
85	46	40	51	57	56	1	39	44
83	47	46	44	50	53	2	56	42
224	47	42	51	41	3	55	50	31

216	49	49	42	26	22	39	50	53
212	50	47	53	45	6	56	44	51
9	51	52	47	24	49	36	40	60
304	52	51	50	40	44	35	44	52
103	53	61	37	67	64	62	7	43
185	54	59	44	51	43	40	35	48
302	55	50	55	2	58	53	63	33
211	56	55	58	54	18	57	32	63
203	57	53	60	15	38	57	52	62
219	58	57	56	58	19	41	59	60
210	58	56	61	10	45	60	60	57
232	60	58	61	36	36	54	60	56
84	61	60	56	65	62	11	54	59
11	62	62	59	13	61	64	65	46
29	63	63	65	62	33	65	55	66
17	64	64	66	14	63	63	66	65
202	65	65	64	31	59	66	64	57
206	66	66	63	20	66	61	60	64
208	67	67	67	59	67	67	67	67

APPENDIX K

Weighted Scores for All LIs Per Outcome

LI No.	Cost	Schedule	Quality	Safety	Satisfaction
1	594	634	425	297	498
2	379	391	341	227	332
3	402	458	312	166	314
4	390	611	165	160	378
5	508	750	220	156	395
6	531	389	235	183	283
7	417	412	309	145	338
8	472	419	241	150	327
9	706	613	227	141	321
10	324	359	211	174	311
11	684	555	323	155	372
12	372	317	434	135	306
13	312	281	394	146	301
14	296	291	154	666	339
15	304	248	223	413	341
16	262	257	178	592	272
17	285	243	177	707	317
18	329	333	198	441	297
19	249	236	188	814	336
20	333	350	231	188	293
21	452	457	295	305	357
22	374	687	210	232	363
23	296	273	388	173	358
24	330	307	262	257	276

25	563	473	329	175	354
26	576	435	236	137	359
27	451	482	251	237	352
28	637	522	190	135	372
29	342	322	200	155	338
30	349	442	193	164	309
31	445	613	180	168	321
32	336	377	404	220	311
33	307	307	251	219	270
34	433	472	225	200	401
35	476	264	152	126	221
36	319	431	155	148	280
37	414	666	187	168	369
38	766	325	187	151	368
39	507	440	218	173	310
40	380	537	322	134	288
41	243	253	208	213	227
42	707	240	179	122	268
43	324	328	201	190	302

APPENDIX L

Definitions of 43 LIs.

Leading Indicator 1
The project team is lacking in the necessary expertise, experience, breadth, and depth to successfully execute the project.

Measurement Considerations

6 The Project Team has several weak or inexperienced members, and the gaps are not being addressed.
7 The Project Team has at least one weak or inexperienced member, whose lack of competency is not being addressed.
8 The Project Team has had to replace and/or augment one or more members after several months of low performance, due to lack of competency or lack of experience.
9 The Project Team assesses its gaps (and generally has few gaps), but only moves to mitigate the problems if pushed by the owner or contractor.
10 The Project Team is experienced and competent. As such, it regularly assesses its gaps (if any) and proactively moves to strengthen the team.

Description

In addition to the Project Managers (see the Leading Indicator on Project Managers), the quality of the entire project team is an important factor in determining project success. The core project team typically consists of Project Engineers, Discipline Engineers (Process, Civil, Mechanical, Electrical, Piping, and Control Systems), Procurement Specialists, and Project Services (estimating, scheduling, cost control).

If the core project team (either the Owner's or the Engineering Contractor's) is weak and inexperienced, the project is not likely to be a success. The Project Manager needs to be able to recognize key deficiencies on the team, and proactively make changes before the project health is endangered. Replacing key individuals or bringing on additional resources are the typical responses to gaps identified in the course of a project.

Source Documents	**References**
• Organization Charts • Team Resumes	• RS134-1 Identifying Success Factors for High Performance Project Teams • RS37-1 Team Building: Improving Project Performance • IR111-3 Core Competency Toolkit

Leading Indicator 2
The project team is experiencing a high turnover rate and instability in team membership.

Measurement Considerations

1. Greater than 15% of Project Team turnover since beginning of the Project, with no process in place to identify reasons for turnover.
2. Greater than 15% of Project Team turnover since beginning of the Project, but there is a process in place to identify reasons for turnover.
3. Less than 15% Project Team turnover since the beginning of the Project. Project has an inadequate process to assess reasons for turnover.
4. Less than 15% Project Team turnover. Project has an adequate process in place to monitor reasons for turnover and plan to integrate new team members.
5. Less than 15% Project Team turnover. Project has an adequate process in place to monitor reasons for turnover and takes action to address root causes of turnover and plan to integrate new team members.

Description

During Project execution phase, consistency in team membership among Owner and Contractor staff can contribute to Project health by establishing team dynamics and norms early in the execution phase for the duration of the Project.

Low turnover of team membership can indicate owners and contractors have confidence in the Project process and are confident of a positive outcome. High turnover of team members on the other hand may indicate the team cannot align or develop to the point where the team is performing effectively. High turnover of team members also maybe an early indicator that the execution of the Project is at risk due to factors associated with human conflicts within the team, conflicting objectives, design issues, lack of commitment to project objectives, team members taking on too much work, contractor companies taking on too much work, team members assigned are under-qualified, or other factors.

Evaluation of this leading indicator requires identification of key team members, ongoing monitoring of the team membership, and investigation into the root cause of changes in membership during execution of the Project.

Source Documents
- Project Organization Charts
- Project Execution Plans

References
- IR200-2 The Future Starts Now: Recommendations for Recruiting and Retaining Future Engineering and Construction Leaders
- IR200-3 Recruiting and Retaining: Company Self-Assessment
- RS37-1 Team Building: Improving Project Performance

Leading Indicator 3
The project team's response to Requests for Information (RFI), questions, and changing events that can significantly impact the project results is slow, inadequate, or incomplete.

Measurement Considerations

1 There is no institutional existence and use of a RFI process.
2 There is an institutional RFI process, but response to RFI’s is not monitored.
3 The response to RFI’s or contractor questions is, on average, quite slow (greater than 5 days) and is causing a schedule delay.
4 The response to RFI’s or contractor questions is 2 to 4 days, on average.
5 The response to RFI’s or contractor questions is 1 day or less, on average.

Description

Requests for Information (RFI) can occur between owners and contractors, designers and vendors, designers and field forces (field data), and between the field forces and designers. Often RFI's are required for design data or the result of drawing errors, interferences, missing details, specifications or vendor information, or newly discovered field conditions. Prompt resolution of RFI's is critical to maintain construction productivity and project schedule.

The measurement tool should be real-time, with data collected and reviewed during Project Team meetings. RFI's should be identified (similar to an Action register) then the open duration tracked and measured against a team goal for RFI turnaround time. The quantity of RFI's is a lagging indicator of design quality, and the response time can be considered leading indicator field productivity and schedule.

Note: The time durations for a response can be project dependent. In some cases, such as on fast track projects or during mill outages or turnarounds, the response time required maybe faster than those stated above. In these cases, it is the timeliness of the response so as not to affect schedule that should be considered.

Source Documents	References
• RFI Register and Log • RFI Response Times	• RS8-1 Evaluation of Design Effectiveness • SD-12 Project Control in Design Engineering • IR7-3 Procurement and Materials Management: A Guide to Effective Project Execution

Leading Indicator 4
The project team is losing confidence in the accuracy and validity of the schedule.

Measurement Considerations

1. The project schedule is not consulted on a weekly basis to monitor progress and set priorities. The team has no confidence in the schedule.
2. The project schedule is consulted on an ad hoc basis by most team members, but doesn't tend to influence work priorities. Multiple inaccuracies have been found in the schedule.
3. The project schedule is regularly used by the Project Controls people, but engineering and/or construction are managing the work by "gut feel". The schedule has some significant inaccuracies.
4. The project schedule is consulted by all key stakeholders, but the sequence of work and critical path shown do not reflect the opinions of key stakeholders.
5. The project schedule is consistently used as a tool by key stakeholders. The general logic and critical path are agreed. The schedule is adjusted as warranted.

Description

There appears to be a lack of alignment amongst the project team members and other key stakeholders associated with the accuracy and validity of the schedule. Confidence in the schedule is paramount. If the validity of the schedule is placed under suspicion, the team loses the sense of urgency toward meeting the schedule target dates due to the diminished confidence in the schedule.

For a schedule to be a key project document, it has to be treated as a "tool" and not a "deliverable". Schedules will change during the course of a project – but the baseline schedule should remain fixed.

Source Documents
- Project Schedule
- Progress Monitoring System (home office and field)

References
- RS12-1 Project Objective Setting, Second Edition
- RS6-1 Project Control for Engineering
- RS6-5 Project Control for Construction
- IR107-2 Continuous Assessment of Project Performance

Leading Indicator 5
Project milestones are not being met and are consequently jeopardizing future project milestones.

Measurement Considerations

1. About half of the key project milestones are not being met. Critical path is slipping.
2. About a third of the key project milestones are not being met. Critical path is slipping.
3. Ten to thirty percent of the key project milestones are not being met. Previous non-critical milestones have become critical.
4. Less than ten percent of the key project milestones are not being met, and these missed milestones may have an effect on the project's critical path.
5. Nearly all of the project milestones are being met. The few missed milestones are not having an effect on the project's critical path.

Description

Critical Path Activities are those activities within a schedule that have no float. Float is a term that refers to the number of days that an activity can slip and still not impact the overall end date of the project. If an activity that used to have 10 days float, now has 5 days of float, one can say that the float for that activity has been used up, which means that that activity is not being finished as the schedule originally showed it being finished. Lack of progress on an activity could be due to insufficient manpower, insufficient materials, a predecessor activity not being finished, or the original activity duration was underestimated.

Reports are reflecting significant numbers of milestones missed. These missed milestones affect the ability to meet downstream milestones, and may have an affect on the project critical path.

Source Documents
- Project Schedule
- List of key project milestones

References
- RS6-1 Project Control for Engineering
- RS6-5 Project Control for Construction
- IR107-2 Continuous Assessment of Project Performance

Leading Indicator 6
Construction is awarded before adequate completion of the project design, including discipline design packages, resulting in an incomplete scope definition at time of award/start of construction.

Measurement Considerations

1. Construction is awarded based on less than AFC quality drawings.
2. Construction is awarded based on AFC drawings for at least 80% of the scope of work.
3. Construction is awarded based on AFC drawings for at least 90% of the scope of work.
4. Construction is awarded based on AFC drawings, but these drawings have significant "Holds", errors, or omissions on them.
5. Construction is awarded based on a complete and thorough set of AFC drawings.

Description

Because change orders and scope creep in the construction phase have the greatest negative impact on cost and schedule, it is critical that design, review, as well as any value engineering be completed prior to awarding of construction bids on a project. Uncertainties resulting from construction that begins or is bid before completion of all engineering and major procurement invariably result in a high incidence of RFI's, change orders, delays or claims from contractors.

In addition to complete drawings, specifications, and a comprehensive Scope of Work, a job walk and constructability reviews should be held with bidders prior to awarding a contract to minimize problems or disputes during construction.

In the above context, AFC stands for Approved for Construction, which is a similar term to IFC (Issued for Construction). It is also considered a common practice to bid construction work with less than AFC quality drawings. However, prior to contract award, the preferred bidder is asked to re-evaluate its bid with the newly issued AFC drawings.

Source Documents
- Scope of Work write ups
- BOM's
- Integrated delivery & construction schedule(s)
- Drawing List with revision dates

References
- RS6-2 Scope Definition and Control
- IR184-2 Value Management Toolkit

Leading Indicator 7
Business goals, project objectives, priorities, and critical success factors are not being consistently used by project team members and key stakeholders to guide decisions.

Measurement Considerations

1 The project does not have written project objectives.
2 The project has written project objectives, but they are not consulted.
3 The project has written project objectives, but they do not clearly prioritize the key project features.
4 The project has written project objectives that prioritize cost, schedule, quality, safety, and operability, but these objectives are not well communicated to all project stakeholders.
5 The project has written project objectives that clearly spell out the relative priorities of cost, schedule, quality, safety, operability, and the project team is using this guidance to make routine decisions.

Description

During Pre Project Planning, it is critical that the Project leaders and Business Leaders decide what is important to that particular project and to document these important factors in a Project Objectives Letter. These written project objectives should be considered a “contract” between the project team and the Business Leaders.

The project objectives should spell out what the key features of the project are, and what the key drivers of the project are. For example, written project objectives should discuss key features of the project such as quality, schedule, cost, safety, and operability. The relative priorities of these key features must be agreed in order to allow the key stakeholders to make good project decisions.

If the project is schedule-driven, that should be spelled out, so that the project team can focus their decision-making efforts on schedule adherence (or schedule reduction). If the project is cost-driven, then the project team needs to use that priority to make decisions to minimize cost.

Some of the projects that perform the worst are those projects that either have no clear priorities, or those projects that seem to change priorities on a routine basis. Without clear leadership and understanding of the key project drivers, the team cannot meet the stakeholder objectives.

Source Documents
- Project Objectives Letter
- Business Objectives Letter
- Organization Charts

References
- RS12-1 Project Objective Setting, Second Edition
- RS6-2 Scope Definition and Control

Leading Indicator 8
Owner and/or contractor are requesting an excessive number of contract changes and/or scope changes during project execution (detailed design, procurement, construction, and start-up)

Measurement Considerations

1. There is no institutional existence and use of a Change Order Process (or Scope Change Process) that includes a forecast of cost and schedule impacts.
2. The current total project Scope and Execution Changes as a percent of original contract value is greater than 10 percent.
3. The current total project Scope and Execution Changes as a percent of original contract value is between 5 and 10 percent.
4. The current total project Scope and Execution Changes as a percent of original contract value is between 2 and 5 percent.
5. The current total project Scope and Execution Changes as a percent of original contract value is less than 2 percent.

Description

A Change is any event that results in a modification of project scope of work, execution plan or standards. Contract changes could also include commercial terms.

Scope Changes are generally detrimental to the health of a project, as they typically have a major impact on cost and schedule, and a lesser impact on quality and safety. It is also well documented that the cumulative impact of a number of small changes is much greater than the sum of the individual impacts.

The measurement tool must take into consideration the contract type, and depending on the type, there may need to be separate contractor and owner measures. This is a quantity measure, which could be defined as the pure number of change requests, or as a percent of contract value.

Source Documents
- Scope Change Log
- Cost Reports
- Trend Change Log

References
- RS5-3 Contract Risk Allocation and Cost Effectiveness
- RS6-2 Scope Definition and Control

Leading Indicator 9
Significant project scope items are omitted from bid packages.

Measurement Considerations

1. To meet the project schedule, bid packages are released with Pre-AFC quality drawings with substantial drawing “Holds,” missing scope, and unspecified quantities.
2. Because of the tight project schedule, bid packages are released with less than 50% AFC Drawings. Much of the design is not yet reviewed or approved. Engineering is incomplete.
3. Most design, review, Value Engineering, and specifications have been completed prior to bid package preparation. Drawings are more than 50% AFC. Work is expected to be awarded with less than AFC quality drawings.
4. The bid package consists of about 90% AFC Drawings. Some “Holds” and scope details are lacking. It is expected that these issues will be resolved before awarding a contract for the work.
5. The bid package consists of all AFC Drawings and specifications, which are of high quality with minimal errors and “Holds”.

Description

Because changes in scope identified after contracts are awarded typically have substantially greater cost and/or schedule impact, it is important to minimize the number and value of changes to Purchase Orders and contracts on a project.

The intentional or erroneous omission of work scope, materials and/or equipment from a Request for Quotation (RFQ) due to the release of bid packages before design and checking is complete, are likely to result in adverse cost and schedule impacts.

It is common during construction to have scope changes due to inaccurate drawings or unknown conditions found in the field during construction. However, if on top of these issues, the bid drawings did not reflect the entire scope of the project, bigger cost and schedule impacts would be expected.

Source Documents

- Scopes of Work
- Bill of Material
- Drawing Revisions list/Drawing Transmittals
- Subcontracting plan or schedule

References

- RS8-1 Evaluation of Design Effectiveness
- RS8-2 Input Variables Impacting Design Effectiveness
- SD-12 Project Control in Design Engineering

Leading Indicator 10
Some project participant companies appear to be financially unstable.

Measurement Considerations

1 Potential default by a major Vendor or principal Contractor without recourse from bonding company.
2 Potential default by a Vendor or Contractor with adequate bonding in place.
3 Complaints or rumors of substantial late payments by contractor or vendor or other indications of financial difficulty (including the loss of key supervisory personnel).
4 Contracts and/or purchase orders awarded to familiar vendors/contractors with inadequate bonding capability or new, unproven vendors/contractors with bids greater than 20% lower than the next lower bid.
5 All vendors and contractors are large, well-managed companies with adequate cash flow and sufficient resources to back a project of this size. They have a history of successful projects of similar size and scope.

Description

The failure by any vendor or contractor to complete its portion of the work can have a severe negative impact on all aspects of a project's success. Replacing Key Stakeholders "mid-stream" will invariably lead to major inconvenience, or schedule delays, or cost overruns. Undue financial pressure on a vendor/ contractor may also adversely affect quality, safety, and stakeholder satisfaction.

The pressure to buy at or below budget can result in selecting contractors or vendors with inadequate financial resources to execute their scope of work. Such pressure can also result in placing untenable losses on otherwise reliable partners.

In some cases, the Owner select a "low ball" bid from a contractor or vendor, knowing that the contractor or vendor is not likely to be able to perform the work for the agreed prices. Bankruptcy or not paying workers or suppliers can result in liens, schedule delays, or non-performance of the work.

Source Documents
- Approved Vendors list
- D&B reports
- Experience list
- Audited Financial Statements

References
- IR102-2 Partnering ToolKit (binder not included)

Leading Indicator 11
The project is experiencing a high level of engineering/design/specification errors and scope changes.

Measurement Considerations

1. The project has consumed all contingency funds during detailed design. Major cost overruns are expected by the completion of construction.
2. The project has experienced serious and time consuming scope changes and/or engineering rework due to errors. Completion of the project within approved funds is in doubt.
3. The project has experienced significant but manageable levels of scope changes and engineering rework due to errors. Final cost is at risk, but careful control during construction should produce a result within budget.
4. The project has experienced few scope changes and/or engineering rework due to errors. Minimal allocations from contingency have been needed. Final costs within budget do not appear to be at risk.
5. The project has few or no or scope change items or engineering rework. Any added costs are offset by savings in other cost areas. A realistic final cost estimate would project no use of contingency funds.

Description

The ability to execute a project on time, on budget, and produce the expected business results is highly dependent upon the front end work. If the proper amount of time and effort was spent by a team composed of all affected business, operating and maintenance functions, towards the agreed project objectives, then an accurate scope of work and cost estimate should have been produced. It is normal for some small errors or oversights will be found during detailed design.

Some problem projects with high levels of errors or scope changes are those that didn't spend adequate time or resources during project development or those where there really wasn't an agreement on the scope definition needed to produce a complete project. Either of these underlying problems will manifest themselves in early and numerous allocations of contingency funds to errors, omissions, and scope changes

A third issue that leads to serious cost and schedule impacts is the late addition of scope, either just before or just after project sanction. These late scope changes often never get fully integrated into the detailed design work flow, and thus cause schedule and cost impacts in excess of what they should.

Source Documents
- The Engineering Monthly Progress Report
- Scope Change Log

References
- RS8-1 Evaluation of Design Effectiveness
- RS8-2 Input Variables Impacting Design Effectiveness
- SD-12 Project Control in Design Engineering
- IR47-2 Tools for Enhancing the Piping Engineering Process

Leading Indicator 12
A project specific quality plan is not consistent with the contract documents (plans and specifications.)

Measurement Considerations

1. Quality plans and specifications are not present in purchasing, engineering and vendor documents. Quality was not considered during project development. Project participants believe quality is someone else's responsibility. Quality is poor and delays are affecting the schedule and cost.
2. Quality plans and specifications are not usually present in purchasing, engineering, vendor and contractor documents. Inconsistencies and conflicts between documents are normal. Virtually no project participants exhibit knowledge of quality expectations. Quality discussions are not normally heard. Quality issues are occurring in the field on a regular basis.
3. Quality plans and specifications are sporadically present in purchasing, engineering, vendor and contractor documents. Inconsistencies and conflicts between documents are frequent. Few project participants exhibit any knowledge of quality expectations. Quality is seldom a part of discussions or is brought up as an afterthought.
4. Quality plans and specifications are usually present in purchasing, engineering, vendor and contractor documents. Inconsistencies and conflicts between documents are minimal. Many project participants exhibit some knowledge of quality expectations. Quality is a part of some discussions concerning the execution of project elements.
5. Quality plans and specifications are present and consistent throughout purchasing, engineering, vendor and contractor documents. All project participants exhibit a consistent focused knowledge of quality expectations. Quality is a part of most discussions concerning the execution of project elements.

Description

The ability of a project to achieve the desired quality results depends on the consistent and persistent application of quality plans and specifications during all phases of the project. The quality definition should start during front end development. Quality plans and specifications should be included during each phase and become more detailed in each subsequent phase. Earlier work should be reviewed with each new document to ensure the consistency of all documents that will go to vendors or contractors.

The application of these principles during all phases of the project will ensure that most quality expectations are met without excessive owner review. Even with a significant quality effort, some small errors or oversights will be found from inspections.

Projects with the most quality problems are usually those that didn't consider quality during project development, but then try to add it or inspect it into the work at a very late stage of the project. These late efforts will cause schedule delays, turmoil and unexpected costs.

Source Documents
- Quality Inspections Reports
- Monthly Project Report
- Monthly Contractor Report

References
- RS5-3 Contract Risk Allocation and Cost Effectiveness

Leading Indicator 13
The project fails to follow the quality plan for construction in relation to the roles and requirements of those who are responsible for the plan.

Measurement Considerations

1 Quality plans and responsibilities are not being followed in the field. Unexpected and unplanned quality input is being received from sources that were not identified as responsible for quality verification. This input is not timely and is not in accordance with agreed upon project quality standards. Schedule issues and cost impacts are the result of this issue.
2 Quality plans and responsibilities are frequently not being followed in the field. Some input is from sources that were not identified as responsible for quality verification. This input is not timely and is not always in accordance with agreed upon project quality standards. Schedule compression and cost concerns are the result of this issue.
3 Quality plans and responsibilities are occasionally not being followed in the field. Occasional input from unexpected sources is causing an extra but manageable amount of work in the field.
4 Quality plans and responsibilities are usually being followed in the field. Quality plans are well documented and supported by all parties. The designated resources are engaged in quality verification at the agreed times. There are few quality issues that can't be solved at the field level.
5 Quality plans and responsibilities are nearly always being followed in the field. Quality plans are well documented and supported by all parties. The designated resources are engaged in quality verification at the agreed times. There are virtually no quality issues that can't be solved at the field level.

Description

The ability of a project to achieve the desired quality results depends on the consistent and persistent application of quality plans and specifications during all phases of the project. Established quality expectations and the roles and responsibilities of those who will be charged with meeting them should be monitored for compliance throughout all phases of the project, especially the construction phase.

All project team members should consider quality to be a part of their responsibility to ensure project success. Casual but frequent quality discussions will be observed during all phases of the work. A procedure to receive quality concerns from those outside the responsible group should be established and communicated. External quality concerns should be investigated and feedback provided to the concerned party.

Projects with the most quality problems are usually those that didn't establish written plans and responsibilities. Confusion, unexpected, inappropriate and untimely quality input will be the result, causing schedule delays, turmoil and unexpected costs.

Source Documents
- Quality Inspections Reports
- Monthly Project Report
- Monthly Contractor Report

References
- RS6-1 Project Control for Engineering
- RS6-5 Project Control for Construction
- RS6-3 Model Planning and Controlling System for EPC of Industrial Projects
- RS6-6 Work Packaging for Project Control
- RS6-8 Management of Project Risks and Uncertainties

Leading Indicator 14
The project is experiencing a high level of safety incidents.

Measurement Considerations

1. The project has several DART injuries in addition to several Recordable injuries and a high volume of first aid cases and safety incidents (DART>1.0, TRR>3.0)
2. The project has a high frequency of Recordable injuries, first aid cases and significant safety incidents without injury. (DART<1.0, TRR>1.0)
3. The project has a few Recordables, along with several first aid cases, and a few significant safety incidents. (DART<0.5, TRR<1.0) All serious safety incidents are investigated and documented, but not much is done with the findings.
4. The project has a few first aid cases and incidents without injury. Incident investigations are documented, but results are not widely shared.
5. The project has a few first aid cases and incidents without injury. Investigations are thorough, results are well communicated, and recommendations are completed in a timely fashion. Safety is dealt with in a very proactive manner.

Description

A significant amount of research has been done in the last 10+ years by CII and others regarding construction and facility safety. This research has looked at many aspects of safety including best practices, planning, incentives, project characteristics, the role of owners, etc. One of the focuses of this research has been the tracking of accidents and incidents, and the response of the team to investigate early accidents and incidents, as a key indicator of future project safety performance.

The OSHA safety frequency is based upon the numbers of accidents per 200,000 man-hours. OSHA publishes annual data for the construction industry. CII also measures the safety statistics for its membership and publishes it as part of its benchmarking effort. The correlation of first aid and near miss incidents to OSHA Recordable accidents is documented throughout CII Target Zero research and Benchmarking. See Reference material list below.

In evaluating the score of this LI, consideration should be given to the frequency of the incidents, the severity of the incidents, and the response of the project team to the incidents. Incidents include fatalities (deaths), DART Cases (accidents that result in Days Away, Restricted, or Transferred), OSHA Recordable Cases (all cases that require more that first aid treatment), First Aid Cases (injuries that are not serious enough to be OSHA Recordable Injuries), near misses (incidents that do not result in an injury but had the potential to cause injury), and general incidents (incidents that did cause, or could have caused, damage to equipment or facilities).

Source Documents
- Safety Incident Reporting
- Incident Investigations

References
- RS 32-1 – Zero Injury Techniques
- IR 32-2 – Zero Injury Economics
- RS 160A-1 – Making Zero Accidents a Reality: Focus on Shutdowns, Turnarounds, and Outages.
- BMM 2004-2 – 2004 Safety Report

Leading Indicator 15
Design reviews fail to include qualified personnel who can analyze safety, ergonomics, and/or loss prevention features of plans and specifications.

Measurement Considerations

1 The project has not included safety and loss prevention personnel in the design reviews.
2 N/A
3 The project has involved safety and loss prevention personnel to a limited extent.
4 N/A
5 The project has included safety and loss prevention personnel in all appropriate design reviews.

Description

As part of the detailed design effort for any project, consideration needs to be made to incorporate safety, industrial hygiene, ergonomics, and loss prevention (Example - Fire Protection) safeguards into a facility. A key part in identifying and designing these safeguards is the involvement of personnel with expertise in each of these areas. This expertise is most useful in design reviews such as Plot Plan reviews, P&ID reviews, and 3D model reviews.

The expertise can come from a variety of sources. In some cases, it may reside as a competency possessed by certain core team members. Other sources may include owner specialists (safety or industrial hygiene professionals), other contractors (Fire Protection specialists), insurance agencies, suppliers (protection requirements for material or equipment provided), etc.

The consequences associated with the failure to incorporate the above expertise into a project, include risks to facility safety and catastrophic loss events. There can also be significant cost and schedule impacts that occur as a result of incomplete facility designs translating into late changes in the scope of the project.

The measurement of this LI is mostly qualitative; *Did the project include the necessary qualified personnel in the design reviews?* Meeting minutes and other documentation maybe a potential source of information regarding the attendance of the necessary personnel at the review meetings.

Source Documents
- Meeting minutes from Design reviews.

References
- RS32-1 Zero Injury Techniques
- RS101-1 Design for Safety
- RS160A-1 Making Zero Accidents A Reality: Focus on Shutdowns, Turnarounds, and Outages
- RS160-1 Safety Plus: Making Zero Accidents A Reality

Leading Indicator 16
The project team personnel lack involvement in safety inspections, awareness of safety issues, and education in safety practices.

Measurement Considerations

1. The project team has little involvement in, or knowledge of, the site (or project) safety plan. Enforcement is limited to safety personnel only.
2. The project team in general has only a limited understanding of the site (or project) safety plan. Enforcement of the safety policy is limited to safety personnel and the project manager only.
3. The project team has read and understands the site (or project) safety plan. There is limited involvement in site safety audits and safety leadership by the project team.
4. The project team has read and understands the site (or project) safety plan. Project team members are encouraged to participate in safety audits and mentoring.
5. The project team has read and fully understands the site (or project) safety plan. All project personnel are involved in auditing and mentoring/training of site workers. Safety is considered a core value and a condition for employment on this project.

Description

A significant amount of research has been done in the last 10+ years by CII and others regarding construction and facility safety. This research has looked at many aspects of safety including best practices, planning, incentives, project characteristics, the role of owners, etc. One of the focuses of this research has been the involvement of the project team, both owner and contractor, in performing inspections, awareness and resolution of safety issues, and on the orientation and education of the construction workers regarding safety practices.

This LI focuses on the involvement of the entire team in project safety. It looks at all levels of management and workers from both the owner and all contractors including project managers, engineers, site superintendents, construction managers, operating and maintenance personnel, foreman, safety specialists, and the craft workers. A failure of the team to involve all personnel in the identification of hazards, task and practice planning, and subsequent compliance inspections can lead to poor project safety performance.

For purposes of this assessment, the evaluation of team involvement is mostly qualitative; *Does the team have the necessary involvement of all stakeholders in the safety planning and enforcement?* A more detailed quantitative evaluation is available through the CII Target Zero Audit process. CII developed a correlation between team involvement and safety performance as part of its research on Target Zero Safety.

Source Documents
- Meeting Minutes
- Site Audit reports
- Target Zero Audit Documentation
- Safety Statistics

References
- RS 32-1 – Zero Injury Techniques
- IR 32-2 – Zero Injury Economics
- RS 160A-1 – Making Zero Accidents a Reality: Focus on Shutdowns, Turnarounds, and Outages.
- BMM 2004-2 – 2004 Safety Report

Leading Indicator 17
Potential safety related problems are not being resolved in a timely manner.

Measurement Considerations

1. The project has resolved few, if any, potential safety problems that have been identified.
2. The project has resolved some of its potential safety problems that are deemed critical.
3. The project gives all potential safety problems a medium priority and resolves them as time and resources allow.
4. The project gives all potential safety problems medium priority and assigns resources to resolve all in a timely fashion.
5. The project gives all potential safety problems a high priority and resolves them in an expeditious manner. All workers are encouraged to identify potential safety issues as part of their routine work.

Description

A significant amount of research has been done in the last 10+ years by CII and others regarding construction and facility safety. This research has looked at many aspects of safety including best practices, planning, incentives, project characteristics, the role of owners, etc. One of the focuses of this research has been the response of the project team, both owner and contractor, to the resolution of potential safety items. The response of the core project team to safety issues is a key indicator regarding the importance the team places on safety performance and how that importance is communicated to the workers.

For purposes of this assessment, consideration should be given to the source and nature of the safety issues and the response of the team as a whole to the issues. Care should be taken to include not only consideration of the resolution planning of the item but also the communication to and implementation with the project team and construction workers. The primary focus of this LI is the response time to resolve safety issues. Secondary considerations should include the quality of field inspections (both formal and informal), encouragement to raise safety issues before an incident occurs, the effectiveness of task planning sessions (includes daily task planning and job specific safety audits), and the effectiveness of safety communications.

Source Documents
- Meeting minutes
- Safety related task durations
- Site audits and field inspection reports.
- Incident and Injury reports

References
- RS 32-1 – Zero Injury Techniques
- IR 32-2 – Zero Injury Economics
- RS 160A-1 – Making Zero Accidents a Reality: Focus on Shutdowns, Turnarounds, and Outages.
- BMM 2004-2 – 2004 Safety Report

Leading Indicator 18
The project is experiencing an increasing level of worker non-compliance in safety practices.

Measurement Considerations

1. The project has experienced a high rate of at-risk behaviors, near misses, and hazardous incidents. Safety policies are not strictly enforced.
2. The project has experienced a moderate rate of at-risk behaviors, near misses, and hazardous incidents. Only serious safety issues are addressed and enforced.
3. The project has experienced a low rate of at-risk behaviors, near misses, and hazardous incidents. Verbal and written notices are given when safety non-compliance actions are seen.
4. The project has experienced a few incidents of at-risk behaviors, near misses, and hazardous incidents. Workers are dismissed for serious safety violations.
5. The project has experienced a few safety incidents. The project has a zero tolerance policy for all safety related practices.

Description

A significant amount of research has been done in the last 10+ years by CII and others regarding construction and facility safety. This research has looked at many aspects of safety including best practices, planning, incentives, project characteristics, the role of owners, etc. One of the focuses of this research has been the development and use of safety practices and pre-task planning.

This LI focuses on the verification that work crews are following the practices and task planning that the team developed. The project team members usually accomplish this verification via both formal site audits and informal observations. Consideration should be given to the volume, severity, and response of the project team to the incidents. CII also measures the safety statistics for its membership and publishes it as part of its benchmarking effort. Most data tracked regarding these observations generally fall within two categories; at-risk behavior and uncontrolled hazards. At-risk behavior incidents are where the worker crews are engaged in behavior that places them at an elevated safety risk (Examples include not wearing proper PPE [personal protective equipment], not following safety practices such as confined space entry or lockouts, or not following task specific safety requirements). Near misses are those incidents that could have caused an injury (or death) if circumstances had been different (if someone would have been standing in the "line of fire"). Uncontrolled hazards are incidents where the task planning and safety practices did not sufficiently address the work hazards.

Source Documents
- Meeting minutes
- Safety related task durations
- Site audits and field inspection reports.
- Safety orientation materials for new workers

References
- RS 32-1 – Zero Injury Techniques
- IR 32-2 – Zero Injury Economics
- RS 160A-1 – Making Zero Accidents a Reality: Focus on Shutdowns, Turnarounds, and Outages.
- BMM 2004-2 – 2004 Safety Report

Leading Indicator 19
The project is not following the requirements of a project specific safety plan during construction.

Measurement Considerations

1. The project does not have a project specific safety plan and the site safety plan either does not exist or is not used.
2. The project has a general safety plan (or uses the site safety plan) that identifies some hazards and the plans for controlling those hazards. Specific job planning is independent of the safety plan.
3. The project has a general safety plan that identifies some hazards and the plans for controlling those hazards. Specific job planning is sometimes conducted based on the safety plan and followed by the construction workers.
4. The project has a detailed project specific safety plan that identifies all hazards and the plans for controlling/mitigating those hazards. The specific job planning is generally conducted based on the safety plan and followed by the construction workers.
5. The project has a detailed project specific safety plan that identifies all hazards and the plans for controlling those hazards. The specific job planning is always conducted based on the safety plan and followed by the construction workers.

Description
A significant amount of research has been done in the last 10+ years by CII and others regarding construction and facility safety. This research has looked at many aspects of safety including best practices, planning, incentives, project characteristics, the role of owners, etc. One of the focuses of this research has been the need to identify project specific hazards and to incorporate them into a project specific safety plan.

This LI focuses on the project team and construction crews following the project specific safety plan. The project specific safety plan general involves several steps. A hazard analysis is performed at the beginning of the project to identify the hazards that need to be addressed. The hazards are then evaluated as to their impact on the tasks that need to be performed. A plan is then developed to provide for the safe implementation of the tasks based analysis of the hazard impacts. This plan then gets communicated to the foremen and workers for use in their daily task planning. A failure of the project team to plan for hazards and to properly follow that plan can lead to poor safety performance on a project. Tools such as a JSA (Job Safety Analysis) can be used to focus workers' thinking about the safety aspects of a specific job.

As a caution, documentation does not always translate into performance. Consideration should be given to the culture of the project (are the workers filling out the task cards because they were instructed to do so or are they using them as a safety tool?) and the attitude of the personnel toward following the safety plan.

Source Documents
- Meeting minutes
- Safety Plan documentation
- Pre Task Planning cards

References
- RS 32-1 – Zero Injury Techniques
- IR 32-2 – Zero Injury Economics
- RS 160A-1 – Making Zero Accidents a Reality: Focus on Shutdowns, Turnarounds, and Outages.
- BMM 2004-2 – 2004 Safety Report

Leading Indicator 20
Owner and contractor project personnel are not properly aligned.

Measurement Considerations

1. The project does not recognize the concept of alignment.
2. The project recognizes the concept of alignment but does not actively work toward stakeholder alignment.
3. The project undertakes and documents at least one formal activity to ensure alignment.
4. The project has an alignment strategy and executes the strategy. Alignment is somewhat based on the written Project Objectives.
5. Project has an alignment strategy, executes the strategy through the execution phase. Alignment is based on the Project Objectives, which are known and understood by the entire team.

Description

Best practices suggest that successful Project outcomes are more likely when stakeholders have common understanding and commitment to Project Objectives. CII defines alignment in the context of capital construction projects 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."

This LI requires identification of Project Objectives and evaluating the degree to which Owner and Contractor staff's have a common understanding of, and commitment to, Project Objectives. The evaluation may include but may not be limited to:

- Assessment of level and mix of Contractor and Owner staff on Project team.
- Identification and evaluation of efforts taken by Project leadership to communicate Project Objectives and ensure common understanding and commitment by all to those objectives.
- Assessment of any team-building or team alignment exercises.
- Identification and evaluation of Project related issues specific to either owner's or contractor's staff which may influence their level of commitment to Project Objectives (i.e., project was underbid, or project does not have sufficient management support).
- Nature of relationship between contractor and owner (i.e., ongoing relationship, new relationship, troubled relationship etc.).

The evaluation should be based on demonstrated behaviors and actions by Project leaders and both Owner and Contractor's staff. Positive behaviors and actions may include owner and contractor staff participation in design reviews, kickoff meetings, progress meetings, look-ahead meetings, development of schedules and milestones, coordination of activities. Signs of good alignment include a joint project team (both Owner and Contractor), open and honest communication, effective dispute resolution, agreement on priorities, and an integrated project schedule that is used by all parties.

Source Documents	References
• Team Alignment Meetings • Project Charter • Project Objectives • Organization Charts	• CII Pre Project Alignment Thermometer • IR102-2 Partnering ToolKit (binder not included) • RS134-1 Identifying Success Factors for High Performance Project Teams • RS37-1 Team Building: Improving Project Performance

Leading Indicator 21
The project lacks sufficient skilled craft and is experiencing high craft turnover due to competition from other projects, low wages, and/or undesirable work schedules.

Measurement Considerations

1. The project is experiencing major craftsmen turnover (greater than 10% per month), resulting in schedule delays.
2. Significant turnover is occurring across several disciplines and productivity losses are being experienced.
3. Significant craftsmen turnover within a specific discipline is being experienced.
4. An event (hurricane, earthquake) or another project have created an environment which is expected to affect craft stability. The project team is proactively managing the situation.
5. No craft turnover issues.

Description

Project completion is dependent on sufficient craft manning and experience level. A high turn-over can be caused by a multitude of issues such as low wages, competition from other jobs, poor working conditions, less desirable work schedules, etc. Under staffing is often exacerbated when there is an insufficient labor pool in the local area (particularly a problem for projects in remote areas). The high turn-over can extend itself into many areas including labor productivity and rework that ultimately may impact project schedule and cause budget overruns.

This Leading Indicator can be quantified in many areas (turn-over by discipline, turn-over by subcontract, turn-over caused by competition, etc.) and should be examined on a routine basis in order to mitigate slippages in performance.

Note: The frequency of craft turnover can be project dependent. In some cases, such as on fast track projects or during mill outages or turnarounds, a lower turnover frequency may have a higher impact due to the schedule sensitivity of the project. In these cases, it is the effect of the turnover to the schedule that should be considered.

Source Documents
- Scheduled Manpower Curves
- Labor Productivity Tracking Reports
- Labor Survey Results
- Safety Reporting
- Cost Reports on labor or rework
- New Worker Orientation records

References
- IR200-3 Recruiting and Retaining: Company Self-Assessment
- RS143-1 Craft Labor Productivity

Leading Indicator 22
The project lacks sufficient staff, bulk materials, small tools, and/or construction equipment to adequately support planned construction activities.

Measurement Considerations

1. Project schedule has experienced MAJOR delays (more than a month) due to a shortage of construction equipment, bulk materials, or rework as a result of inadequate supervision.
2. Project schedule has experienced MINOR delays (more than a week) due to a shortage of construction equipment, bulk materials, or rework as a result of inadequate supervision.
3. Significant standby time, low productivity, or rework is being experienced at the project.
4. Minor standby time or excess rework is occurring.
5. The project is not suffering from a shortage of construction equipment, bulk materials, or inadequate supervision.

Description

This question examines the infrastructure to support the construction effort and the impact of potential shortages to the performance of the project in terms of schedule, cost, and quality. The infrastructure examined includes the staff setup to administer the construction work, the availability of bulk materials, and the availability of construction tools and equipment (cranes, welding machines, air compressors, etc.). Identifying issues timely and developing resolution strategies for this type of problem is necessary for good project health, but can be severe and costly to both owner and contractor.

Problems in this area may be known prior to the beginning of the field construction. A shortage in infrastructure (often called Field Indirects) can result in schedule performance problems, quality issues, and/or budget slippages. In some cases it may be hard to directly measure a deficiency in Field Indirects, but low worker productivity and an excess of "standby time" are clues of a problem in the area.

Source Documents
- Scheduled – Baseline vs. Actual
- QA/QC reports
- Change order log – inefficiency claims.
- Cost Reports

References
- IR7-3 Procurement and Materials Management: A Guide to Effective Project Execution
- IR200-3 Recruiting and Retaining: Company Self-Assessment
- RS6-9 Planning Construction Activity to Support the Startup Process

Leading Indicator 23
The level of maintenance and reliability personnel involvement in detailed design is low and the personnel lack alignment with other project team personnel with respect to maintenance issues for the facility.

Measurement Considerations

1. There are no maintenance and reliability personnel involved in the detailed design of the facility.
2. There is minimal maintenance and reliability personnel involvement, such as for identifying spare parts.
3. Maintenance and reliability personnel attend project meetings and review design drawings and specifications, but either don't provide comments, or their comments are ignored.
4. Maintenance and reliability personnel attend project meetings and review design drawings and specifications. They have few comments, that are generally incorporated, but then they attempt to make additional changes later during construction.
5. Maintenance and reliability personnel are fully engaged as part of the project team, and provide early input into existing facility conditions, layout, access, standardization of equipment, documentation, reliability targets, and spare parts requirements.

Description

This is basically an alignment issue. Several possibilities exist:

- Either the Maintenance and Reliability personnel are not aware of the project, or
- The Owner does not have the resources to satisfy this key element of the Detailed Design, or
- The budget is so tight that no money exists to incorporate maintenance and reliability issues.

To encourage Maintenance and Reliability personnel involvement in the detailed design, several steps should be taken, such as: Set Reliability targets for each new facility in the Project Objectives; Ensure that maintenance resources are available to review equipment specs, order spare parts, and standardize features such as pump seals or couplings; Ensure that the overall layout is conducive to maintenance; Ensure that the budget (or cost estimate) is based on the appropriate level of redundant equipment and the quality needed to meet the target uptime.

Many of these activities will need to begin during Pre-Project Planning, but will continue with greater effort in detailed design.

Source Documents
- Meeting Minutes
- Document and Drawing Review Comments
- Reliability Plans and Targets
- Maintenance requirements
- Purchase orders for spare parts

References
- RS6-9 Planning Construction Activity to Support the Startup Process
- RS8-1 Evaluation of Design Effectiveness
- IR121-2 Planning for Startup
- IR142-2 Design for Maintainability Guidebook

Leading Indicator 24
The project is using new technology or construction practices that are unproven in commercial or industrial use.

Measurement Considerations

1. New technology or construction practices have drastically increased project cost or schedule performance (greater than a ten percent increase).
2. New technology or construction practices are starting to impact cost or schedule performance (a five to ten percent increase).
3. The project is using some (or much) new technology or construction practices. It is too soon to quantify any cost or schedule impacts, but potential for some adverse impacts exists.
4. The technology and construction practices planned for this project are only slightly different from standard technology or practices. No adverse impacts are expected.
5. No new technology or construction practices are envisioned for this project.

Description

This question assesses the impact of unproven technologies or construction practices, and their affect on project success. The use of new technologies might involve an operator less bull dozer, a new piece of equipment, a new project management application, the utilization of a new forming system, new robotic welding of piping components, laser scanning an existing facility for a major revamp, or other direct construction process improvements. The effect of using a new technology may be associated with a loss of productivity, increased quality issues, or higher costs. As a worst case, new technology can impact the overall project success.

This leading indicator is relatively easy to measure as most projects are aware of any new practices or equipment being used on the project. The rating given in this area should consider the use of this new technology in relation to critical path activities or work sequences.

Source Documents	References
• Scheduled – Baseline vs. Actual • Contractor Change Requests • Cost Reports • Quality Reports	• RS8-1 Evaluation of Design Effectiveness • IR184-2 Value Management Toolkit

Leading Indicator 25
The project team is failing to identify and/or address missing requirements during detail design reviews.

Measurement Considerations

1. There is no Owner participation from Operations, Maintenance, and Construction representatives.
2. There is only limited Owner participation from Operations, Maintenance, and Construction, in terms of timing and expertise. Team members are not visualizing the construction and operational implications of the drawings. Few comments are generated.
3. There is some Owner participation from Operations, Maintenance, and Construction, but the team members are not asking thoughtful questions and making timely comments. Some of the key issues are being addressed.
4. There is significant Owner participation from Operations, Maintenance, and Construction. However, not all issues are resolved to the satisfaction of these groups, due to late input or non-budgeted costs.
5. Owner participation from Operations, Maintenance, and Construction is thorough. People are fully engaged, asking key questions and resolving these issues.

Description

During the course of detail design, documents are reviewed by the Owner in design review meetings, or via document packages routed for review. This indicator relates both to the competency of the review team, the makeup of the review team, and the level of commitment. In some cases, the Owner does not commit the resources to do an adequate review in the time allowed in the project schedule. In other cases, the design work is poorly done, or is incomplete, leading to revision, re-review and schedule slip.

Typical missed requirements would include maintenance issues (sufficient valves to allow on-line maintenance, blinding locations, access to instruments), reliability issues (equipment monitoring such as vibration and temperatures), construction and turn-around issues (crane access, catalyst dumping and loading), and operational issues (start up requirements, equipment draining, and off-design cases).

Source Documents

- Meeting Minutes
- Document Review Comments
- Design Review Comments
- Start up Planning Documents

References

- IR47-2 Tools for Enhancing the Piping Engineering Process
- RS8-1 Evaluation of Design Effectiveness
- SP12-2 Organizing for Project Success
- RS134-1 Identifying Success Factors for High Performance Project Teams

Leading Indicator 26
The level of detail and the scope covered in the funding authorization estimate are not per the estimating guidelines.

Measurement Considerations
The assessment consists of a comparison of the written procedure identifying what minimal information and criteria be met to support a capital funding grade estimate with the actual estimate details

1. The estimate and backup information do not follow any of the criteria defined in the capital funding grade estimating procedure.
2. A significant portion of the estimate lacks adequate alignment with the criteria defined in the capital funding grade estimating procedure.
3. Some fairly "big ticket" cost accounts within the estimate lack adequate alignment with the criteria defined in the capital funding grade estimating procedure.
4. Some fairly small insignificant cost accounts within the estimate lack adequate alignment with the criteria defined in the capital funding grade estimating procedure.
5. All estimate cost accounts are in alignment with the criteria defined in the capital funding grade estimating procedure.

Description
A typical estimate made at the time of authorization is a +/- 10 percent estimate. Extensive engineering work must be done prior to generating this estimate, or the quality of the estimate will be lacking. Typical information that feeds the Authorization Estimate is as follows:

Written Scopes of Work
P&ID's
Plot Plans
General Arrangement Drawings
Equipment List
Line List
Instrument List
Piping Specialty Items List
Motor Load Tabulation and Preliminary Cable Schedule
Equipment Quotations (for at least 80% of the equipment costs)
Levels of Contingency and Escalation to be applied

Estimate Assumptions, including details for direct cost (labor productivity and labor rates), details for indirect cost (supplies, tools, supervision), and Contracting Strategy (lump sum, reimbursable, unit rates, direct hire, subcontractors).

One of the common problems with Authorization Estimates is a significant scope change either just before or just after Authorization. Often the Authorization Estimate is higher than originally planned or desired, so scope is cut to bring the estimate more in line with expectations. These late scope cuts (or scope additions) are sometime estimated improperly. Additionally, the impact on the design effort of a late scope change is seldom fully accounted for.

Source Documents
- Authorization Cost Estimate
- Change Orders
- Estimating Guidelines

References
- RS6-1 Project Control for Engineering
- SD-6 Control of Construction Project Scope

Leading Indicator 27
The project manager (or team leader) is lacking in the required level of experience and skills.

Measurement Considerations

1 Project Manager is inexperienced and lacks many of the skills needed to lead the project to success.
2 Project Manager has little to no previous project management experience, and his or her skills have not been proven.
3 Project Manager is highly skilled, but lacks significant project experience.
4 Project Manager is skilled and somewhat experienced, having done at least one similar job in the past.
5 Project Manager is experienced and highly qualified, having done at least two similar jobs in the past.

Description

The project managers for both the Owner and the Engineering Contractor(s) play key roles in ensuring the success of the project. While a complete listing of Project Manager experience and skills would be lengthy, the following list are known to be key elements: proactivity, skill in negotiation, good listening skills, a strong engineering background, the ability to motivate project team members, the ability to sift through the chaff and deal with important issues, the ability to communicate clearly and openly the key principles or objectives of the project, the ability to set priorities and make solid decisions, and to deal fairly with all project stakeholders.

Project Managers who are weak leaders, have little understanding of the project they are undertaking, or who have poor people skills, will likely cost their projects in terms of schedule, cost, and quality. Similarly, changing a Project Manager during the course of the project has been found to be a significant negative factor on a project's success.

Source Documents
- PM Resumes
- Organization Charts

References
- IR200-2 The Future Starts Now: Recommendations for Recruiting and Retaining Future Engineering and Construction Leaders
- IR200-3 Recruiting and Retaining: Company Self-Assessment
- IR134-2 Tools for Effective Project Team Leadership
- IR111-3 Core Competency Toolkit
- RS37-1 Team Building: Improving Project Performance

Leading Indicator 28
Project changes are not being processed in a timely manner for decision making (includes defining cost and mark-up rates, evaluating schedule impact, obtaining appropriate approval authority, and initiating dispute resolution procedures).

Measurement Considerations

1. There is no institutional existence and use of a Change Order Process that includes cost and schedule forecasting.
2. There is a change order process, but no clear definition of Scope Change vs. Scope Variance, and the required approval levels.
3. There is a period metric that measures elapsed time from Identification to Approval for Open Change Orders and Change orders closed in that period, and the period metric is greater than the duration target.
4. The average elapsed time for change processing is equal to the project target.
5. The average elapsed time for change processing is less than the project target.

Description

A Change is any event that results in a modification of project work, schedules or cost. Project changes are classified as either a "Scope Change" or a "Scope Variance". The definition of a scope change is anything that changes the Process Flow Sheet and/or Project Scope Document that were used as the basis of the authorization estimate. A Scope Variance (Variance within Scope) is a cost impact not caused by a Scope Change, but caused by a variance in material quantities, material pricing, labor rates, labor productivity, etc.

In either case, project changes disrupt project plans (budgets and resources) leading to rework, schedule delays and contract disputes. Processing a Scope Change requires definition, evaluation, recommendation and approval. Approval of a Scope Change may require approval by a higher authority. Processing a Scope Variance requires definition and approval by the project team. The faster project changes are processed, the lower the impact on project resources cost and schedules.

Source Documents

- Period Metric Measure
- Duration from identification to definition to approval
  a. (Y1,Y2),X Curve
     i. X: Time
     ii. Y1: Current Pending Changes
     iii. Y2: Processed Changes

References

- IR125-2 Determining the Impact of Process Change on the EPC Process
- RS6-3 Model Planning and Controlling System for EPC of Industrial Projects
- SD-6 Control of Construction Project Scope
- IR23-2 Prevention and Resolution of Disputes Using Disputes Review Boards

Leading Indicator 29
Key project stakeholder(s) is (are) exhibiting poor relationships and pursuing private agendas.

Measurement Considerations

1 Strong indications of interpersonal conflict or lack of respect among stakeholders. Evidence of scope creep, schedule variances. No indication of effort to resolve these issues among stakeholders. Poor communication among stakeholders. Project milestones are not met.
2 Some evidence of poor relationships or conflict among stakeholders which is unresolved. Project milestones are not met.
3 Stakeholders work together, evidence of commitment to Project Objectives. Timelines and deliverables are generally met.
4 Project timelines, cost and accomplishment targets are always met.
5 Project leadership proactively works to ensure common interests among stakeholders. Project Objectives and targets are being achieved.

Description

Key project stakeholders may have interests which are not consistent with, and may indeed conflict with, project objectives. For internal stakeholders, examples of private agendas may include issues such as:

Trying to add in "nice-to-have" scope items that were not included in project scope, or
trying to cover up errors or omissions in the design effort, or
internal political maneuverings – trying to make oneself look good at the expense of another party, or
issuing drawings or documents that are known to be incomplete, just so schedule is maintained.

Traditionally Contractors and Owners relationships may not have recognized the importance of "win/win" scenarios and tended to focus on "win/lose" strategies. In a team approach, a "win/lose" agenda may influence relationships.

Left unchecked these interests may negatively impact project health and project outcomes. Left unchecked, these stakeholders may also impact project team by negatively influencing relationships among team members. Early detection and management of these stakeholders and their conflicting interests are critical to project health.

Source Documents
- Project Reports
- Project Objectives
- Actual Schedule versus Plan

References
- IR23-2 Prevention and Resolution of Disputes Using Disputes Review Boards
- RS12-1 Project Objective Setting, Second Edition
- RS6-2 Scope Definition and Control

Leading Indicator 30
Commitments are increasingly made with the intention of not being met and are almost always not met.

Measurement Considerations

1. Commitments are nearly always missed (promised dates to provide information and decisions to outside parties), with no apologies or explanation.
2. The project team misses more than half of its commitment dates.
3. The project team misses less than half of its commitment dates.
4. The project team misses a few commitments to provide information and decisions to the Owner/Contractor/Vendors, but nearly always warns in advance that it will be late.
5. The project team nearly always meets its commitments to provide information, decisions and/or direction to other parties.

Description

In the context of this Leading Indicator, "commitments" refers to project team commitments, such as schedule, action items, and RFI's (Requests for Information).

All projects involve a series of activities. Some of these activities are critical path and some are not. However, the timeliness of any activity affects those activities that are dependent on the results of the original activity. Even a non-critical activity can become critical if it is not dealt with in a timely manner.

This indicator basically addresses the responsiveness of the project team to the need for additional information or decisions. Action Items are generally defined as those issues that arise during the engineering phase of the project, where the Owner or Contractor must supply information or direction to the other parties to enable them to finish their work. Requests for Information (RFI's) are generally defined as issues that arise during construction, where the construction contractor needs additional information or clarification from the Owner or Engineering Contractor.

Source Documents
- RFI Procedure and Log of Issues
- Copies of Action Item Lists
- Organization Charts

References
- IR193-3 Project Manager's Playbook for Radical Reduction in Project Cycle Time
- RS6-1 Project Control for Engineering
- RS6-3 Model Planning and Controlling System for EPC of Industrial Projects

Leading Indicator 31
The project is experiencing difficulties in integrating schedules between project participants.

Measurement Considerations

1. Schedule cannot be integrated.
2. Some phases of the schedule cannot be integrated.
3. Difficulties exist in integrating the schedule and will take significant time and resources to fix.
4. Minor difficulties exist in integrating the schedule but can be overcome.
5. The project schedule is fully integrated, with no outstanding non-scheduled activities.

Description

Variables and inconsistencies within each project participants' schedule logic and activity designations create a hurdle when tying them together to create an integrated project schedule. These various project participants typically include various field subcontractors, owner requirements, various third party engineering shops and construction management teams.

Source Documents

- Project Schedules
- Start up Schedule

References

- RS6-1 Project Control for Engineering
- RS6-3 Model Planning and Controlling System for EPC of Industrial Projects
- RS6-6 Work Packaging for Project Control
- IR107-2 Continuous Assessment of Project Performance

Leading Indicator 32
The project is frequently asking vendors, suppliers, service providers, and contractors to perform functions outside their areas of expertise and experience.

Measurement Considerations

1. The project is using new technology or inexperienced suppliers/contractors to such an extent that major portions of the project are being undertaken by companies working in areas of marginal expertise.
2. The project is very limited in its selection of vendors, suppliers, or contractors, and is asking several vendors and/or contractors to work outside their normal areas of expertise.
3. The project is using a few contractors to provide services outside their known areas of expertise (for example, asking a mechanical contractor to do instrument work).
4. The project is using a few vendors to provide equipment that is new or beyond the normal equipment supplied by that vendor.
5. The project is using vendors, suppliers, service providers, and contractors to supply goods and services that are routinely supplied by these entities.

Description

All projects make use of vendors, suppliers, and contractors to achieve the project objectives. Successful projects use vendors, suppliers, and contractors to do the things that they do well. On a craft level, we say, "use the right tool for the job." On a project level, the best projects use the right vendor, or supplier, service provider, or contractor for the job at hand.

Many vendors, suppliers, service providers, or contractors are very hesitant to say no to a good customer. Therefore, when an Owner asks a contractor if it can do this piece of work, or make this piece of equipment, the answer might come back as "yes", even though the vendor or contractor has no expertise in this area. Therefore, Owners should carefully evaluate the vendor, supplier, or contractor to see if the work is really in their area of expertise.

In a similar manner, a contractor can pressure a preferred supplier to commit to services or materials that it is not used to supplying. The Project Procurement Plan should provide guidance to the procurement of materials and services to help ensure that this situation does not occur.

Source Documents	References
• Project Execution Plan • Procurement Plans	• IR7-3 Procurement and Materials Management: A Guide to Effective Project Execution • RS130-1 Reforming Owner, Contractor, Supplier Relationships: A Project Delivery System to Optimize Supplier Roles in EPC Projects

Leading Indicator 33
Process Hazard Analysis (PHA) is late and/or is experiencing an excessive number of operational/support items that are not complete during the design phase.

Measurement Considerations

1 The project has not conducted a PHA (and it is required).
2 The PHA was late and incorporation of the recommendations into the project scope is incomplete.
3 Most of the PHA was conducted during the design phase, but some of the fringe areas of the project did not have a formal PHA. Implementation of recommendations is incomplete.
4 The project completed the PHA during the design phase. Incorporation of the recommendations into the project scope is incomplete.
5 The project completed the PHA during the design phase and all items have been incorporated into the project scope in a timely fashion.

(If a PHA is not required, please check N/A)

Description

A Process Hazard Analysis (PHA) is an integral part of industrial loss management programs whose goal is to minimize the probability and consequences of a facility incident resulting in injury or property damage (with related public relations, legal and operational impacts). The PHA study identifies and evaluates operating hazards and operability problems, highlights existing safeguards, and recommends additional safeguards.

A PHA can be implemented uses several methods, but they generally concentrate on unintended events, the risks associated with the events, and an evaluation of the potential consequences. A PHA can be as simple as a ‘what if’ checklist, or an evaluation of failure modes, to a study as formal as an OSHA PSM HAZOP.

Failure to incorporate PHA recommendations can result in elevated risks in facility safety. The timing of not addressing them during the design phase of the project can also result in late changes that have a significant cost and schedule impact.

The evaluation of this LI should be based upon the timing of the PHA study, and the follow-up on operational / support items that result from the PHA. Note that a PHA may not be necessary for certain projects, such as Commercial Projects. Those projects should score this LI as Not Applicable.

Source Documents
- PHA Study documentation
- Project schedule
- List of PHA Recommendations and their resolutions

References
- RS8-1 Evaluation of Design Effectiveness
- RS101-1 Design for Safety
- RS160-1 Safety Plus: Making Zero Accidents A Reality

Leading Indicator 34
The project team is not being realistic and truthful when project circumstances are unfavorable.

Measurement Considerations

1. Measurable results are not consistent with written and verbal progress reports. Regular Project monthly meetings are not taking place or are not effective.
2. Progress reports are frequently late. Project leaders are evasive when discussing project performance. Project monthly review meetings are not effective.
3. Regular monthly progress reports are issued and meetings are held. Any bad news is typically buried in the report and not discussed unless the issue is pressed.
4. Project monthly review meetings are held regularly. Schedule and cost issues are discussed openly.
5. Project monthly review meetings are held regularly. Questions pertaining to schedule and cost issues are welcomed and addressed in an open and meaningful way. Business leaders and other stakeholders not on the core project team are invited to participate.

Description

Open and honest communications during project execution help ensure positive project results, and facilitate early identification of problem areas or unfavorable circumstances. Early identification of problem areas or unfavorable circumstances gives the Project Team maximum time to make course corrections to lead to better outcomes. This LI helps identify Projects where communication of bad news is not happening effectively or in a timely manner.

Source Documents
- Project Execution Plans
- Monthly Progress Reports

References
- IR200-2 The Future Starts Now: Recommendations for Recruiting and Retaining Future Engineering and Construction Leaders
- IR134-2 Tools for Effective Project Team Leadership
- RS134-1 Identifying Success Factors for High Performance Project Teams

Leading Indicator 35
Actual installed bulk material quantities are greater than estimated or forecasted total bulk material quantities (e.g., steel, concrete, straight run pipe, electrical wire and cable.)

Measurement Considerations

1. There is no institutional existence and use of a cost control system that includes cost and schedule forecasting.
2. The project cost estimate did not include a risk analysis to set contingency with consideration of bulk material quantities.
3. The actual bulk quantities are greater than the estimated or forecast quantities and are greater than the project contingency allowance.
4. The actual bulk quantities are greater than the estimated or forecast quantities and are less than project contingency allowance.
5. There are no changes in actual bulk materials installed versus estimated or forecast.

Description

During Detailed Engineering it is common practice to do material take-offs for all bulk material (steel, concrete, pipe, fittings, cable, cable tray, conduit, etc.). One common method for forecasting cost is to monitor the installed bulk material quantities as compared to the estimated or forecast quantities. If installed quantities are equal to or less than the estimated quantities, the project cost is normal healthy. If installed quantities are significantly greater than estimated quantities, the project cost is in jeopardy.

The forecast can be done by creating a "control estimate", i.e. an estimate based on issue for construction drawings, or by using the change order management system to document as a Variance within Scope.

Source Documents
- Control Estimate
- Material Take-Offs from Construction Drawings.

References
- CII Pre-Project Planning
- IR7-3 Procurement and Materials Management: A Guide to Effective Project Execution
- RR172-11 Improving Capital Projects Supply Chain Performance
- RS8-1 Evaluation of Design Effectiveness

Leading Indicator 36
Float for project activities is being used up at an increasingly high rate.

Measurement Considerations

1 Many previous non-critical activities are now critical.
2 A few previous non-critical activities are becoming critical.
3 Previous non-critical activities are reaching the threshold of becoming critical.
4 Some float is being eroded.
5 Float is being maintained.

Description

Critical Path Activities are those activities within a schedule that have no float. Float is a term that refers to the number of days that an activity can slip and still not impact the overall end date of the project. If an activity that used to have 10 days float, now has 5 days of float, one can say that the float for that activity has been used up, which means that that activity is not being finished as the schedule originally showed it being finished. Lack of progress on an activity could be due to insufficient manpower, insufficient materials, a predecessor activity not being finished, or the original activity duration was underestimated.

If the float report is reviewed from one month to the next, one can easily see if the float durations are shrinking, and thus float is being used up.

Source Documents
- Project Schedules
- Critical Path Activities (number of activities with less than 3 days float)

References
- RS6-1 Project Control for Engineering
- RS6-5 Project Control for Construction
- RS6-3 Model Planning and Controlling System for EPC of Industrial Projects

Leading Indicator 37
Actual schedule activities are lagging behind planned scheduled activities over several reporting periods.

Measurement Considerations

1. The entire critical path has shifted beyond its planned dates, and previous non-critical activities are now becoming critical.
2. Critical path activities have slipped beyond their planned dates, but float remains on sub-critical activities.
3. A significant number of non-critical activities are being delayed, but the critical path is stable.
4. Some activities have lagged behind their planned dates, but they are non-critical and can be completed without becoming critical to the project.
5. Actual progress is tracking in accordance with planned schedule progress, and there are no delays.

Description

Critical Path Activities are those activities within a schedule that have no float. Float is a term that refers to the number of days that an activity can slip and still not impact the overall end date of the project. If an activity that used to have 10 days float, now has 5 days of float, one can say that the float for that activity has been used up, which means that that activity is not being finished as the schedule originally showed it being finished. Lack of progress on an activity could be due to insufficient manpower, insufficient materials, a predecessor activity not being finished, or the original activity duration was underestimated.

If an activity is not being completed as scheduled, the critical path could be affected. If, over the course of several months, activities are not being completed as planned, the critical path will almost surely be affected, and the project end date will be in jeopardy.

Source Documents
- Project Schedules
- Critical Path Activities (showing activities with less than 3 days float)

References
- RS153-1 The Field Rework Index: Early Warning for Field Rework and Cost Growth
- SD-74 Guidelines for Implementing TQM in the Engineering and Construction Industry
- SD-80 Project Performance Modeling: A Methodology for Evaluating Project Execution Strategies
- IR193-3 Project Manager's Playbook for Radical Reduction in Project Cycle Time
- RS6-1 Project Control for Engineering
- RS6-5 Project Control for Construction

Leading Indicator 38
Forecasts-to-complete based on actual project experience, actual commitments, and actual expenditures are projecting overruns.

Measurement Considerations

1 Current project progress and costs are not monitored closely enough to know if performance is according to plan or not.
2 Project costs and progress are being monitored, but the accuracy of the performance-to-date is questionable, so no forecasting can be made.
3 Project costs and progress are being monitored. The project cost is projected to overrun by at least 10 percent.
4 Project costs and progress are being monitored. The project cost is projected to overrun by less than 10 percent.
5 Project costs and progress are being closely monitored. Forecasting is routinely done, and project leadership uses the forecasts to guide their actions. No cost overrun is projected.

Description
An assessment of estimated hours and/or costs to finish the remaining facility components based on past experience and remaining requirements. This assessment applies to all components of a project including:

Direct construction (e.g., field labor, material and equipment, and subcontracts);
Indirect field construction support (e.g., field staff, temporary facilities, and construction equipment);
Engineering, design, and project management and;
Contingency.

The assessment can focus on specific disciplines, areas, and/or the entire project, both in the office and at the field site.
The assessment is based on past information and data such as the rate of expenditures, drawings completed, construction quantities placed to date, labor production rates to date, obligations to purchase permanent facility materials and equipment, designer and craft profiles, and percent progress to date. The assessment is also based on future requirements such as drawings to complete, quantities of materials to be placed, materials and equipment required to purchase, and anticipated staffing levels to support design, procurement and construction remaining requirements. The combination of past history and future projections provide totals that are compared to current budgets. Overruns and underruns are identified.

Assessment of both past information and data and future needs require input from many different project team members and reports. A project controls engineer typically gathers this information and data and develops the forecasts-to-complete for project management review and action. The underlying premise of this analysis is that future performance is not likely to vary widely from performance-to-date. This allows the project to extrapolate performance-to-date into the future.

Source Documents

- Cost reports
- Schedules (base line and current)

References

- IR193-3 Project Manager's Playbook for Radical Reduction in Project Cycle Time
- RS6-1 Project Control for Engineering
- RS6-5 Project Control for Construction
- RS6-3 Model Planning and Controlling System for EPC of Industrial Projects

Leading Indicator 39
The project is experiencing an above normal level of construction rework hours and costs when compared to target levels of rework included in the total budget or schedule.

Measurement Considerations

1 Quality is poor and delays are affecting the schedule and cost. Cost impacts are in excess of .5% of construction costs.
2 Quality is substandard and delays are affecting the schedule and cost. Cost impacts are in excess of .3% of construction costs.
3 Quality is average. Quality issues are impacting schedule and cost but are manageable. Cost impacts are in the range of .1% - .2% of construction costs.
4 Quality is good. Few quality issues are found during routine inspections. Schedule and cost issues are not being created by the few items found that require rework. Cost impacts are in the range of .1% of construction costs.
5 Quality is excellent. Little rework is required after inspections. Cost impacts are less than .1% of construction costs.

Description

The ability to of a project to produce the desired quality results depends on the consistent and persistent application of quality plans and specifications during all phases of the project. The quality definition should start during front end development. Quality plans and specifications should be included during each phase and become more detailed in each subsequent phase. Earlier work should be reviewed with each new document to ensure the consistency of all documents that will go to vendors or contractors. Quality expectations should be a part of all meetings with potential vendors or contractors. The timing and frequency of quality verification during fabrication or construction should be discussed during the bidding process.
All project team members should consider quality to be a part of their responsibility to ensure project success. Casual but frequent quality discussions should occur during all phases of the work.
Construction contractors normally include some portion of construction funds in their estimate for construction rework. Although these totals may vary by industry, a 1% construction allowance for rework is generally accepted in an estimate. As much as 20-30% of that 1% may be attributed to rework to conform with agreed to quality expectations. Some small errors or oversights will be found during inspections, so some modest amount of field rework is to be expected.
For construction jobs that are “Lump Sum”, quality problems may not impact cost, but will certainly impact schedule.

Source Documents
- Quality Inspections Reports
- Monthly Project Report
- Monthly Contractor Report

References
- CII Publication 10-2 May, 1989
- IR184-2 Value Management Toolkit
- IR203-2 Zero Field Rework Self-Assessment Opportunity Checklist
- IR166-3 CII Best Practices Guide: Improving Project Performance, Second Edition
- RS153-1 The Field Rework Index: Early Warning for Field Rework and Cost Growth

Leading Indicator 40

Project quality control results are reflecting high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.

Measurement Considerations

1. Project is experiencing major rework and delays due to rejection of poor quality materials and/or workmanship of critical equipment/fabrication or installed materials.
2. Rejection of currently non-critical equipment/fabrication is being experienced. Serious rework and delays are occurring.
3. Higher than normal rejection rates of equipment/fabrication could potentially lead to significant rework and delays.
4. Normal levels of rework and schedule problems are occurring.
5. Very little rework or repair is required at routine vendor shop visits or during routine field inspections, causing little or no project delay.

Description

The quality requirements for a given piece of equipment or construction element should spell out what the key expectations of the project are, how often inspections are desired, and what notifications should be provided prior to an inspection. Fabrication, fit and weld expectations should be clearly communicated. Established fabrication and welding standards should be used whenever possible. Additional requirements such as PMI (Positive Material Identification), painting inspections, or metal thickness readings, must be spelled out in advance.

Some of the projects with the most quality problems are projects that didn't consider quality requirements during pre project planning, and try to impose the standards after the work has already started. Without clear standards and communication during early stages of the project it is very hard to get consistent quality results from vendors and contractors.

Source Documents

- Project Quality Plans
- Equipment Purchase Order Quality Plans
- Inspection Reports at Vendor Shops

References

- IR7-3 Procurement and Materials Management: A Guide to Effective Project Execution
- RS130-1 Reforming Owner, Contractor, Supplier Relationships: A Project Delivery System to Optimize Supplier Roles in EPC Projects

Leading Indicator 41
The project is experiencing difficulties due to a lack of understanding of cultural differences.

Measurement Considerations

1. Significant cultural differences exist, which are not well recognized by key stakeholders.
2. Significant cultural differences exist, some of which are recognized and managed on an ad hoc basis.
3. Significant cultural differences exist and are recognized and being dealt with very proactively.
4. Only minor cultural differences exist (perhaps with a vendor or supplier).
5. Cultural differences have had no impact on the project.

Description

While many project experience cultural differences, the key factor is to recognize and understand the impact of these differences. There is no quantitative measure of this Leading Indicator, however a qualitative indication can be made. For those projects that are dealing with multiple languages, in multiple time zones, in different cultures, with differing values, the Owner's project team must take the lead in dealing with potential cultural differences. This leadership could take the form of team alignment meetings with key stakeholders, full time translators to help with language differences, regularly schedule face-to-face meetings (instead of phone calls), and training and exposure to the other party's culture. Cultural differences can be experienced in a number of different areas. Some of these are easily seen and identified, while others are harder to quantify and compensate.
Some of the obvious cultural differences could include the following:

- Differences in native language. People speaking in a language that is not their native tongue are likely to have more difficulty communicating well.
- Differences in time zones. When working a project that covers vast time differences, it is sometimes hard to arrange times when all parties can discuss issues over the phone and resolve conflicts.
- Differences in religion. Different religions have different holy days (Friday, Saturday, or Sunday). Different religions have differing standards of what is considered proper or improper. All of these factors can adversely impact a project if not understood.
- Differences in engineering units. Many areas of the world calculate and feel comfortable with SI units (meters, grams, seconds, calories, Celsius, etc.), while other areas of the world think and feel in English units (feet, pounds, hours, BTU's, Fahrenheit, etc.). In some cases it may be harder for the owner or contractor to check calculations and data sheets to ensure accuracy.

Some of the not-so-obvious cultural differences could include the following:

- Differences in the value of time. Some cultures place a high value on timeliness and meeting deadlines. Other cultures are more relational oriented, and place low value on keeping a rigid schedule.
- Differences in the meaning of yes. In some cultures, when a person says "yes", it means that he or she agrees to do whatever was discussed. In other cultures, "yes" means something more like, "I understand what you are saying."
- Differences in honoring commitments. In some cultures, a verbal agreement and a hand shake are all that are required to do business. In other cultures, extensive written agreements are generated in an attempt to cover all possible contingencies.
- Differences in safety culture. Some areas of the world place an extreme value on working safely. In other areas of the world, safety is not an area of focus, and the temptation is to just allow accidents to happen, because they were destined to occur.
- Differences in gender. While it is still not the norm to find women leading major projects, in some areas of the world, a woman project leader would be quite unwelcome to the local stakeholders.

Source Documents	References
• Project Execution Plan • Procurement Plans • Organization Charts	• IR181-2 International Project Risk Assessment (IPRA)

Leading Indicator 42
Material and/or equipment prices are increasing rapidly for certain types of materials/equipment that represents a high percent of the project cost.

Measurement Considerations

1 Material/equipment shortages are causing contract failure and/or significant schedule delays.
2 Material/equipment shortages are generating escalation claims and creating potential for contract or performance issues.
3 Material/equipment shortages are creating delivery slippages, expediting costs, and/or escalation claims.
4 ENR or other economic indicators are forecasting material shortages or escalating prices.
5 Material/equipment prices are stable and available.

Description

Many contracts provide protection to the Owner regarding material escalation, but these contracts may be ineffective during periods of large material/equipment shortages or periods of strong economic times. The project may be using smaller subcontractors who cannot absorb the cost of these impacts and would subject a hit to their bond or simply walk from the job to forego the impact of high escalation. In most cases, the contractor or supplier will be looking to recover some of their increased costs which will result in additional strain on the project cost and schedule.

This question examines the impact of price escalation on projects in terms or material or equipment shortages. A material shortage similar to the steel shortages of recent years can result in pricing guarantees being useless, as increases in prices are so severe that some subcontractors were willing to walk away and suffer the consequences rather than absorb the costs. Alternatively, if the escalation occurs prior to awarding contracts, the Owner may directly see the increased costs for materials.

Source Documents
- Scheduled – Baseline vs. Actual
- Field Discussions
- Change order log – escalation claims.
- Cost Reports

References
- IR7-3 Procurement and Materials Management: A Guide to Effective Project Execution
- RS130-1 Reforming Owner, Contractor, Supplier Relationships: A Project Delivery System to Optimize Supplier Roles in EPC Projects
- RR130-11 PEpC: A Breakthrough Project Delivery System That Improves Performance by Reforming Owner, Contractor, Supplier Relationships
- RR172-11 Improving Capital Projects Supply Chain Performance

Leading Indicator 43
The client and/or upper management is frequently making unreasonable requests (includes setting unrealistic goals.)

Measurement Considerations

1. There is no Project Objectives Document that has been approved my Operations and Business Management.
2. There is a Project Objectives Document but is not used by the Project Team. Owner's management feels empowered to redirect the Project Team at will.
3. Management continues to change the project objectives and/or make unreasonable requests of the project team. The Project Team is doing what it has been told, but has not determined the impact on budget and schedule.
4. Management has occasionally changed the project objectives or priorities. The project team has determined the impact on budget and schedule before agreeing to do as directed.
5. There have been no changes in the Project Objectives since final authorization. The Owner's management has not made any unreasonable requests.

Description

For project goals to be meaningful, they must be based on rational information, such as resources loaded Critical Path Method (CPM) Schedule, and an authorization grade cost estimate (± 10%). If the client or management is setting arbitrary goals (that are contrary to what was agreed in the Project Objectives), or goals driven by factors outside of the project team's control (such as market window), then the project is likely to fail, unless the Project Team can load the schedule or validate the estimate to prove these goals.

If the project team and management are not aligned on the project goals prior to Authorization, the project success is at risk. If, after Authorization and during execution, the owner or management changes the goals, then a fundamental project change has occurred and the schedule and estimate must be re-loaded to validate the new goals. Management must be informed via the Change Management Process of the impact on the project schedule and cost.

Source Documents
- Project Objectives Document (Letter)
- PDRI Score
- Schedule Change Notices
- Cost Re-Forecasts

References
- CII PDRI
- CII Pre-Project Planning
- RS12-1 Project Objective Setting, Second Edition
- RS6-2 Scope Definition and Control

APPENDIX M

LIs Assigned to Eight Project Practices

Groups	Leading Indicators
Alignment	1. The project team is lacking in the necessary expertise, experience, breadth, and depth to successfully execute the project.
	7. Business goals, project objectives and priorities, and critical success factors are not being consistently used by project team members and key stakeholders to guide decisions.
	23. The level of maintenance and reliability personnel involvement in detailed design is low and the personnel lack alignment with other project team personnel with respect to maintenance issues for the facility.
	27. The project manager (or team leader) is lacking in the required level of experience and skills.
	30. Commitments are increasingly made with the intention of not being met and are almost always not met.
	32. The project is frequently asking vendors, suppliers, service providers, and contractors to perform functions outside their areas of expertise and experience.
	41. The project is experiencing difficulties due to the lack of understanding cultural differences.
	43. The client and/or upper management is frequently making unreasonable requests (includes setting unrealistic goals.)
Change Management	3. The project team's response to Requests for Information, questions, and changing events that can significantly impact the project results is slow, inadequate, or incomplete.
	8. Owner and/or contractor is requesting an excessive number of contract changes and/or scope changes during project execution (detailed design, procurement, construction, and start up.)
	25. The project team is failing to identify and/or address missing requirements during detail design reviews.
	28. Project changes are not being processed in a timely manner for decision making (includes defining cost and mark-up rates, evaluating schedule impact, obtaining appropriate approval authority, and initiating dispute resolution procedures.)
Constructability	21. The project lacks sufficient skilled craft and is experiencing high craft turnover due to competition from other projects, low wages, and/or undesirable work schedules.
	22. The project lacks sufficient staff, bulk materials, small tools, and construction equipment to adequately support planned construction activities.
	24. The project is using new technology or construction practices that are unproven in commercial or industrial use.

	42. Material and/or equipment prices are increasing rapidly for certain types of materials/equipment that represent a high percent of the project cost.
Contracting	6. Construction is awarded before adequate completion of project design, including discipline design packages, resulting in an incomplete scope definition at time of award/start of construction.
	9. Significant project scope items are inadvertently omitted from bid packages.
	10. Some project participant companies become financially unstable.
Quality Management	11. The project is experiencing a high level of engineering / design / specification errors and scope changes.
	12. A project specific quality plan is not consistent with the contract documents (plans and specifications.)
	13. The project fails to follow the quality plan for construction in relation to the roles and requirements of those who are responsible for that plan.
	39. The project is experiencing an above normal level of construction rework hours and costs when compared to target levels of rework included in the total budget on schedule.
	40. Project quality control results are reflecting high rejection rates for equipment and materials under fabrication in the factory and/or materials in place through testing in the field.
Safety Practice	14. The project is experiencing a high level of safety incidents.
	15. Design reviews fail to include qualified personnel who can analyze safety ergonomics, and/or loss prevention features of plans and specifications.
	16. The project team personnel lack involvement in safety inspections, awareness of safety issues, and education in safety practices.
	17. Potential safety related problems are not being resolved in a timely manner.
	18. The project is experiencing an increasing level of worker non compliance in safety practices.
	19. The project is not following the requirements of a project specific safety plan during construction.
	33. Process Hazard Analysis (PHA) is late and/or is experiencing an excessive number of operational/support items that are not complete during the design phase.

Project Control	4. The project team is losing confidence in the accuracy and validity of the schedule.
	5. Project milestones are not being met and are consequently jeopardizing future project milestones.
	26. The level of detail and the scope covered in the funding authorization estimate are not per estimating guidelines.
	31. The project is experiencing difficulties in integrating schedules between project participants.
	35. Actual installed bulk material quantities are greater than estimated or forecasted total bulk material quantities (e.g., steel, concrete, straight run pipe, electrical wire and cable.)
	36. Float for project activities is being used up at an increasingly high rate.
	37. Actual schedule activities are lagging behind planned scheduled activities over several reporting periods.
	38. Forecasts-to-complete based on actual project experience, actual commitments, and actual expenditures are projecting overruns.
Team Building	2. The project team is experiencing a high turnover rate and instability in team membership.
	20. Owner and contractor project personnel are not properly aligned.
	29. Key project stakeholder(s) is (are) exhibiting poor relationships and pursuing private agenda.
	34. The project team is not being realistic and truthful when project circumstances are unfavorable.

APPENDIX N

Two Sets of Testing Protocols

Research Team 220 Leading Indicators of Project Outcomes
Leading Indicator Tool Testing Protocol
Evaluating Leading Indicator Tool on Completed Projects

PART I. Testing Approach

Purpose:

1. To check the validity of the Leading Indicator Tool

Materials for testing:

1. Leading Indicator Tool
2. Descriptions of Leading Indicators

Evaluation Procedure:

1. Select projects that have been recently completed
   a. Two projects that were completed recently (one considered successful and one considered not so successful).

2. Select evaluators – need to find someone who is close to the project and can go back and make an evaluation as if they were working the project
   a. Select one (or more) people listed below who had worked for the project
      i. Operation manager,
      ii. Project manager,
      iii. Senior project manager,
      iv. Engineering manager,
      v. Construction manager,
      vi. Superintendent,
      vii. Project control manager, or
      viii. Someone who had experience on the project with a similar title

3. Choose appropriate timing for evaluation – for contractors this choice must reflect your company's involvement in the project
   a. Suggested points of time for project evaluation:
      i. when 40 to 60% of detailed design was completed - this is past pre-project planning,
      ii. 40 to 60% of construction completed, or
      iii. Pick the percent complete.

4. Applications – two options given below
   a. Use of the tool – by one evaluator
      i. Read the Definitions of Leading Indicators until they are fully understand

ii. Read instructions in the tool (Excel File) and provide appropriate evaluator information
iii. Read each Leading Indicator in the tool, recall the situation at the point of percent completion, and select the appropriate scale based on the measurement consideration in the LI Definitions.
iv. Save the Excel file tool as an identifiable name (e.g. combination of project ID, evaluator ID, and the point of time) and print the result.
v. Consider the next point in time and repeat the procedure "iii" and "iv," as necessary (if evaluating both design and construction phases of same project).
vi. Evaluator should review results – dial gauges for project health parameters and by CII Best Practice Groups. The evaluator should assess whether the dial gauges are showing realistic results relative to the overall actual performance of the project.
vii. Complete the Part II Questionnaire concerning the project and results (see Questionnaire below).

b. Use the tool – if more than one evaluator
   i. Evaluators read the Definitions of Leading Indicators until they are fully understand
   ii. Evaluators read instructions after opening the tool (Excel File)
   iii. Each evaluator reads each Leading Indicator in the tool
   iv. Evaluators discuss LI status with regard to the project and then together select the appropriate scale based on the measurement consideration in the LI Definitions.
   v. One evaluator inputs the appropriate response for the LI in the Excel spreadsheet (provide appropriate evaluator information)
   vi. One evaluator saves the tool as an identifiable name (e.g. combination of project ID, evaluator ID, and the point of time) and prints the result.
   vii. Consider the next point in time and repeat the procedure "iii," "iv,"and "v," as necessary (if evaluating both design and construction phases of same project).
   viii. Evaluators should review results together – dial gauges for project health parameters and by CII Best Practice Groups. The evaluators should assess whether the dial gauges are showing realistic results relative to the overall actual performance of the project.
   ix. Complete the Part II Questionnaire concerning the project and results (see Questionnaire below).

Research Team 220 Leading Indicators of Project Outcomes
Leading Indicator Tool Testing Protocol
Evaluating Leading Indicator Tool on Completed Projects

Part II. Questionnaire for Evaluation of Test

Evaluator Information

1. Company Name:
2. Company Characteristic:
   a. ☐ Owner
   b. ☐ Contractor/Engineer/Designer
3. Project ID:
4. Project Location (City or County, State and/or Country):
5. Evaluator:
6. Evaluator's Phone:
7. Evaluator's Fax:
8. Evaluator's e-mail:

Project Characteristic

1. Project Description – Choose a Project Type which best describes the project (check only one)
   a. Heavy Industrial
      i. ☐ Chemical Manufacturing
      ii. ☐ Electrical (Generating)
      iii. ☐ Environmental
      iv. ☐ Metals Refining/Processing
      v. ☐ Mining
      vi. ☐ Natural Gas Processing
      vii. ☐ Oil Exploration/Production
      viii. ☐ Oil Refining
      ix. ☐ Pulp and Paper
      x. ☐ Pipeline
      xi. ☐ Gas Distribution
      xii. ☐ Other Heavy Industrial (Please describe):
   b. Light Industrial
      i. ☐ Automotive Manufacturing
      ii. ☐ Consumer Products Manufacturing
      iii. ☐ Foods
      iv. ☐ Microelectronics Manufacturing
      v. ☐ Office Products Manufacturing
      vi. ☐ Pharmaceutical Manufacturing
      vii. ☐ Pharmaceutical Labs
      viii. ☐ Clean Room (Hi-Tech)
      ix. ☐ Other Light Industrial (Please describe):

c. Buildings
   i. ☐ Communications Center
   ii. ☐ Dormitory/Hotel/Housing/Residential
   iii. ☐ Low rise Office (≤3 floors)
   iv. ☐ High rise Office (>3 floors)
   v. ☐ Hospital
   vi. ☐ Laboratory
   vii. ☐ Maintenance Facilities
   viii. ☐ Parking Garage
   ix. ☐ Physical Fitness Center
   x. ☐ Restaurant/Nightclub
   xi. ☐ Retail Building
   xii. ☐ School
   xiii. ☐ Warehouse
   xiv. ☐ Prison
   xv. ☐ Movie Theatre
   xvi. ☐ Courthouse
   xvii. ☐ Embassy
   xviii. ☐ Other Buildings (Please describe):

d. Infrastructure
   i. ☐ Airport
   ii. ☐ Electrical Distribution
   iii. ☐ Flood Control
   iv. ☐ Highway
   v. ☐ Marine Facilities
   vi. ☐ Navigation
   vii. ☐ Rail
   viii. ☐ Tunneling
   ix. ☐ Water/Wastewater
   x. ☐ Telecom, Wide Area Network
   xi. ☐ Other Infrastructure (Please describe):

2. Project Nature (check only one)
   a. ☐ Grass Roots
   b. ☐ Modernization
   c. ☐ Addition
   d. ☐ Other (Please describe):

3. Project Drivers – Select the primary driver influencing the execution of this project (check only one)
   a. ☐ Cost
   b. ☐ Schedule
   c. ☐ Quality
   d. ☐ Safety
   e. ☐ Stakeholder satisfaction

f. ☐ Other (Please describe):
g. ☐ No primary driver

Project Involvement

Check Project Phase when evaluation is considered and enter approximate percent complete corresponding to when the evaluation is made.

Project Phase		Percent Complete At Time of Evaluation
Detail Design	☐	
Procurement	☐	
Construction	☐	
Total Project	☐	

Project Performance

1. Budgeted and Actual Project Cost by Phase (only include budget and actual cost for Project Phase in which you where involved)

Project Phase	Baseline Budget (Including Contingency)	Actual Phase Cost
Detail Design		
Procurement		
Construction		
Startup		
Total Project		

2. Planned and Actual Project Schedule (only include planned and actual schedule for Project Phase in which you where involved)

Project Phase	Baseline Schedule		Actual Schedule	
	Start mm/dd/yyyy	Stop mm/dd/yyyy	Start mm/dd/yyyy	Stop mm/dd/yyyy
Detail Design				
Procurement				
Construction				
Startup				
Overall Project				

Leading Indicator Tool Evaluation

Please address the following questions regarding this application test of the Leading Indicator Tool (LI Tool)

1. Did the LI Tool results agree with your expectations for the evaluation?
   a. If the project was successful did the dial gauges indicate a healthy project at the evaluation point (e.g., green)? Please discuss.

   b. If the project was not as successful did the dial gauges indicate a project that wa not healthy at the evaluation point (e.g., red)? Please discuss.

2. If you had the tool at the time of the evaluation and the tool results indicated a potential problem (e.g., yellow or red dial gauges) would the tool have provided you with sufficient information to identify specific problem areas? Please discuss.

3. How long did it take to complete the evaluation using the tool?

   a. First use 0 hours
   b. Second use 0 hours
   c. Other uses 0 hours

4. Please provide comments on the use of the tool in this specific application knowing that the tool is designed for use in real time.

NOTE: PLEASE RETURN THE EXCEL FILE(s) AND THE COMPLETE PART II QUESTIONNAIRE.

Research Team 220 Leading Indicators of Project Outcomes
Leading Indicator Tool Testing Protocol
Evaluating Leading Indicator Tool on Current Projects

PART I. TESTING APPROACH

Purpose:

1. To check project health of a current and on-going project using the Leading Indicator Tool

Materials for testing:

1. Leading Indicator Tool
2. Descriptions of Leading Indicators

Evaluation Procedure:

1. Select projects that are currently in progress and have not been completed
   a. Any two active projects where in the project's health can be assessed.
   b. Projects that have been authorized for design and construction (are passed pre-project planning process) and have progressed into design and/or are less than 50% complete with construction.

2. Select evaluators
   a. Select one or more people listed below who are actively involved in the project, either working full time on the project or managing the project or responsible for overall project performance
      i. Operation manager,
      ii. Project manager,
      iii. Senior project manager,
      iv. Engineering manager,
      v. Construction manager,
      vi. Superintendent,
      vii. Project control manager, or
      viii. Someone who has an equivalent position and/or experience in project work

3. Choose appropriate timing for project health evaluation
   a. Suggested points of time for project evaluation:
      i. when 40 to 60% of detailed design is complete,
      ii. when 40 to 60% of construction is complete, or
      iii. select the percent complete for the particular project phase in which the evaluation will be performed.

4. Applications – three options given below
   a. Use of the Tool – by one in-house evaluator
      i. Read the Definitions of Leading Indicators until they are fully understand
      ii. Read instructions in the tool (Excel File) and provide appropriate evaluator information
      iii. Read each Leading Indicator in the tool, and select the appropriate scale based on the measurement consideration in the LI Definitions.
      iv. Save the Excel file tool as an identifiable name (e.g. combination of project ID, evaluator ID, and the point of time) and print the result.
      v. Evaluator should review results – dial gauges for project health parameters and by CII Best Practice Groups. If the dial gauges show a potential problem (e.g., yellow or red) the evaluator should determine where the problem exists and what actions might be taken.
      vi. Complete the Part II Questionnaire concerning the project results and the use of the Tool (see Questionnaire below)

   b. Use of the Tool – by one in-house evaluator and one client or contractor representative
      i. Each evaluator reads the Definitions of Leading Indicators until they are fully understand
      ii. Each evaluator reads instructions after opening the tool (Excel File) and provide appropriate evaluator information
      iii. Each evaluator reads each Leading Indicator in the tool, and selects the appropriate scale based on the measurement consideration in the LI Definitions.
      iv. Save the Excel file tool as an identifiable name (e.g. combination of project ID, evaluator ID, and the point of time) and print the result.
      v. Evaluator should review results – dial gauges for project health parameters and by CII Best Practice Groups. If the dial gauges show a potential problem (e.g., yellow or red) the evaluator should determine where the problem exists and what actions might be taken.
      vi. Two evaluators should compare responses and results and discuss.
      vii. Complete the Part II Questionnaire concerning the project results and the use of the Tool (see Questionnaire below)

   c. Use of the Tool – by more than one in-house evaluator in group setting
      i. Evaluators read the Definitions of Leading Indicators until they are fully understand
      ii. Evaluators read instructions after opening the tool (Excel File)
      iii. Each evaluator reads each Leading Indicator in the tool
      iv. Evaluators discuss LI status with regard to the project and then together select the appropriate scale based on the measurement consideration in the LI Definitions.
      v. One evaluator inputs the appropriate response for the LI in the Excel spreadsheet (provide appropriate evaluator information)

vi. One evaluator saves the tool as an identifiable name (e.g. combination of project ID, evaluator ID, and the point of time) and prints the result.
vii. Group should review results – dial gauges for project health parameters and by CII Best Practice Groups. If the dial gauges show a potential problem (e.g., yellow or red) the evaluator should determine where the problem exists and what actions might be taken.
viii. Complete the Part II Questionnaire concerning the project results and the use of the Tool (see Questionnaire below)

Research Team 220 Leading Indicators of Project Outcomes
Leading Indicator Tool Testing Protocol
Evaluating Leading Indicator Tool on Current Projects

PART II. QUESTIONNAIRE FOR TOOL TESTING RESULTS

Evaluator Information

1. Company Name:
2. Company Characteristic:
   a. ☐ Owner
   b. ☐ Contractor/Engineer/Designer
3. Project ID:
4. Project Location (City or County, State and/or Country):
5. Evaluator:
6. Evaluator's Phone:
7. Evaluator's Fax:
8. Evaluator's e-mail:

Project Characteristic

1. Project Description – Choose a Project Type which best describes the project (check only one)
   a. Heavy Industrial
      i. ☐ Chemical Manufacturing
      ii. ☐ Electrical (Generating)
      iii. ☐ Environmental
      iv. ☐ Metals Refining/Processing
      v. ☐ Mining
      vi. ☐ Natural Gas Processing
      vii. ☐ Oil Exploration/Production
      viii. ☐ Oil Refining
      ix. ☐ Pulp and Paper
      x. ☐ Pipeline
      xi. ☐ Gas Distribution
      xii. ☐ Other Heavy Industrial (Please describe):
   b. Light Industrial
      i. ☐ Automotive Manufacturing
      ii. ☐ Consumer Products Manufacturing
      iii. ☐ Foods
      iv. ☐ Microelectronics Manufacturing
      v. ☐ Office Products Manufacturing
      vi. ☐ Pharmaceutical Manufacturing
      vii. ☐ Pharmaceutical Labs
      viii. ☐ Clean Room (Hi-Tech)
      ix. ☐ Other Light Industrial (Please describe):

c. Buildings
   i. ☐ Communications Center
   ii. ☐ Dormitory/Hotel/Housing/Residential
   iii. ☐ Low rise Office ($\leq$3 floors)
   iv. ☐ High rise Office (>3 floors)
   v. ☐ Hospital
   vi. ☐ Laboratory
   vii. ☐ Maintenance Facilities
   viii. ☐ Parking Garage
   ix. ☐ Physical Fitness Center
   x. ☐ Restaurant/Nightclub
   xi. ☐ Retail Building
   xii. ☐ School
   xiii. ☐ Warehouse
   xiv. ☐ Prison
   xv. ☐ Movie Theatre
   xvi. ☐ Courthouse
   xvii. ☐ Embassy
   xviii. ☐ Other Buildings (Please describe):

d. Infrastructure
   i. ☐ Airport
   ii. ☐ Electrical Distribution
   iii. ☐ Flood Control
   iv. ☐ Highway
   v. ☐ Marine Facilities
   vi. ☐ Navigation
   vii. ☐ Rail
   viii. ☐ Tunneling
   ix. ☐ Water/Wastewater
   x. ☐ Telecom, Wide Area Network
   xi. ☐ Other Infrastructure (Please describe):

2. Project Nature (check only one)
   a. ☐ Grass Roots
   b. ☐ Modernization
   c. ☐ Addition
   d. ☐ Other (Please describe):

3. Project Drivers – Select the primary driver influencing the execution of this project (check only one)
   a. ☐ Cost
   b. ☐ Schedule
   c. ☐ Quality
   d. ☐ Safety
   e. ☐ Stakeholder satisfaction

f. ☐ Other (Please describe):
g. ☐ No primary driver

Project Involvement

Check Project Phase when the evaluation is being conducted and enter approximate percent complete for that phase.

Project Phase		Percent Complete at Time of Evaluation
Detail Design	☐	
Procurement	☐	
Construction	☐	
Total Project	☐	

Project Performance

1. Budgeted and Current Forecasted Project Cost by Phase (only include budget and current forecasted cost for Project Phase in which you where involved)

Project Phase	Baseline Budget (Including Contingency)	Current Forecasted Phase Cost
Detail Design		
Procurement		
Construction		
Startup		
Total Project		

2. Planned and Current Forecasted Project Schedule (only include planned and current forecasted schedule for Project Phase in which you where involved)

Project Phase	Baseline Schedule		Current Forecasted Schedule	
	Start mm/dd/yyyy	Stop mm/dd/yyyy	Start mm/dd/yyyy	Stop mm/dd/yyyy
Detail Design				
Procurement				
Construction				
Startup				
Overall Project				

Leading Indicator Tool Evaluation

Please address the following questions regarding this application test of the Leading Indicator Tool (LI Tool)

1. LI Tool results agree with your expectations for the evaluation
    a. If the project is meeting or exceeding all performance outcomes, does the dial gauges indicate that the project is healthy at the time of evaluation (e.g., green)? Please discuss.

    b. If the project is not meeting one or more of the performance outcomes does the dial gauges indicate that the project is not healthy at the time of evaluation (e.g., red)? Please discuss.

2. If the tool results indicated a potential problem(s) (e.g., yellow or red dial gauges) does the tool provide you with sufficient information to identify the specific problem areas so that you can take actions to resolve the problem(s)? Please discuss.

3. How long did it take to complete the evaluation using the tool?

    a. First use <u>0</u> hours
    b. Second use <u>0</u> hours
    c. Other uses <u>0</u> hours

4. How often would you evaluate project health using the tool?

5. Do you have any suggestions for improving the tool, customizing the tool to better fit your application within your company?

6. Please provide any comments on the use of the tool in this specific application.

NOTE: PLEASE RETURN THE EXCEL FILE(s) AND THE COMPLETE PART II QUESTIONNAIRE.

APPENDIX O

Normalized Weight Scores of 43 LIs for Outcomes per Each Weight Option

Cost

LI No.	W1	W2	W3	W4	W5
1	33	44	49	48	43
2	21	16	10	6	3
3	22	16	9	5	2
4	21	17	11	6	3
5	28	32	32	27	21
6	29	31	28	22	16
7	23	19	13	8	5
8	26	21	14	8	5
9	39	67	99	127	147
10	18	9	4	2	1
11	38	66	97	125	146
12	20	17	12	8	4
13	17	11	6	3	1
14	16	8	3	1	0
15	17	10	5	2	1
16	14	9	4	2	1
17	16	10	5	2	1
18	18	11	5	2	1
19	14	7	3	1	0
20	18	13	8	4	2
21	25	22	17	11	7
22	21	15	9	5	2

23	16	11	6	3	1
24	18	10	5	2	1
25	31	42	48	48	43
26	32	39	41	38	31
27	25	23	18	12	8
28	35	52	64	70	69
29	19	12	6	3	1
30	19	12	6	3	1
31	25	28	28	24	18
32	19	12	6	3	1
33	17	9	4	2	1
34	24	20	14	9	5
35	26	23	17	11	7
36	18	10	5	2	1
37	23	21	17	12	7
38	42	82	135	193	250
39	28	28	23	17	11
40	21	15	9	5	2
41	13	6	2	1	0
42	39	66	94	116	131
43	18	9	4	2	1

Schedule

LI No.	W1	W2	W3	W4	W5
1	36	57	77	91	97
2	22	17	11	6	3
3	26	23	17	11	6
4	34	45	50	49	43
5	42	84	141	207	277
6	22	16	10	5	2
7	23	20	15	10	6
8	24	17	10	5	3
9	34	51	65	71	72
10	20	12	7	3	1
11	31	41	45	43	37
12	18	13	8	5	2
13	16	10	5	2	1
14	16	9	4	1	1
15	14	7	3	1	0
16	14	10	6	3	1
17	14	7	3	1	0
18	19	11	5	2	1
19	13	6	2	1	0
20	20	15	10	5	3
21	26	22	15	10	5
22	39	66	96	122	141

23	15	9	5	2	1
24	17	9	4	2	1
25	27	29	28	23	17
26	24	23	19	13	9
27	27	29	25	20	14
28	29	33	32	26	20
29	18	11	5	2	1
30	25	19	13	7	4
31	34	51	65	71	72
32	21	18	13	8	5
33	17	9	4	2	1
34	27	26	22	16	11
35	15	6	2	1	0
36	24	17	11	6	3
37	37	60	82	97	105
38	18	10	4	2	1
39	25	22	17	11	7
40	30	36	37	33	26
41	14	6	2	1	0
42	14	6	3	1	0
43	18	10	5	2	1

Quality

LI No.	W1	W2	W3	W4	W5
1	40	67	101	140	179
2	32	45	57	67	72
3	29	39	48	53	54
4	16	11	7	4	2
5	21	23	23	21	17
6	22	22	20	17	13
7	29	32	32	29	25
8	23	21	18	14	10
9	21	15	10	6	3
10	20	13	8	5	2
11	30	34	35	33	28
12	41	68	104	143	184
13	37	50	62	70	73
14	15	9	5	2	1
15	21	14	9	5	3
16	17	12	8	5	3
17	17	13	9	6	4
18	19	13	8	4	2
19	18	15	12	8	5
20	22	18	14	9	6
21	28	26	21	16	11
22	20	13	8	4	2

23	37	51	63	73	77
24	25	21	16	11	7
25	31	34	34	31	26
26	22	20	17	13	9
27	24	20	16	11	8
28	18	12	7	4	2
29	19	12	7	4	2
30	18	11	6	3	2
31	17	13	9	6	4
32	38	56	76	93	106
33	24	18	13	8	5
34	21	15	10	6	3
35	14	11	8	5	3
36	15	11	8	5	3
37	18	19	18	16	14
38	18	14	10	6	4
39	21	15	9	6	3
40	30	28	24	19	13
41	20	14	10	6	3
42	17	15	12	8	6
43	19	13	8	4	2

Safety

LI No.	W1	W2	W3	W4	W5
1	29	17	6	2	0
2	22	12	4	1	0
3	16	8	3	1	0
4	16	8	2	1	0
5	15	9	3	1	0
6	18	13	5	2	1
7	14	4	1	0	0
8	15	6	2	0	0
9	14	5	1	0	0
10	17	7	2	0	0
11	15	8	2	1	0
12	13	7	3	1	0
13	14	7	2	0	0
14	65	119	134	113	85
15	40	37	21	9	3
16	58	94	95	72	48
17	69	154	213	221	203
18	43	39	22	9	3
19	79	230	410	550	652
20	18	9	3	1	0
21	30	20	8	2	1
22	23	11	3	1	0

23	17	8	2	0	0
24	25	15	6	2	0
25	17	8	3	1	0
26	13	6	2	0	0
27	23	12	4	1	0
28	13	6	2	0	0
29	15	5	1	0	0
30	16	6	1	0	0
31	16	8	3	1	0
32	21	10	3	1	0
33	21	8	2	0	0
34	19	8	2	0	0
35	12	7	3	1	0
36	14	8	3	1	0
37	16	12	5	2	1
38	15	8	3	1	0
39	17	11	4	1	0
40	13	5	1	0	0
41	21	9	2	0	0
42	12	7	3	1	0
43	19	8	2	0	0

Satisfaction

LI No.	W1	W2	W3	W4	W5
1	35	62	102	160	237
2	24	23	22	20	17
3	22	20	17	14	11
4	27	33	38	42	44
5	28	37	47	56	63
6	20	18	16	13	10
7	24	22	19	15	12
8	23	20	17	14	10
9	23	19	15	12	8
10	22	21	18	16	12
11	26	29	30	30	28
12	22	21	19	17	14
13	21	21	19	16	13
14	24	21	18	14	11
15	24	27	28	28	27
16	19	15	11	8	5
17	23	20	17	13	10
18	21	16	12	8	5
19	24	25	24	23	20
20	21	17	14	10	7
21	25	28	30	30	28
22	26	31	36	40	41

23	26	32	37	42	44
24	20	16	13	10	7
25	25	28	30	30	29
26	26	27	27	26	23
27	25	26	26	25	22
28	26	29	30	30	28
29	24	21	17	13	10
30	22	17	12	9	6
31	23	23	22	20	17
32	22	23	23	21	19
33	19	14	9	6	4
34	29	34	39	42	44
35	16	10	5	3	2
36	20	18	15	12	9
37	26	34	42	49	55
38	26	27	26	24	21
39	22	21	19	16	13
40	21	15	11	7	5
41	16	9	5	3	1
42	19	14	9	6	4
43	22	17	12	8	6

APPENDIX P

Memorandum and Questionnaires Used for the Tool Validation Test

MEMORANDUM

Date: January 23, 2006

To: CII Member Companies

From: Kevin Gierc, Research Team Chair, Dick Corporation
Paul Ennis, Research Team Co-Chair, U.S. Steel
Stuart Anderson, Research Team Academic, Texas A&M University
CII Research Team 220, Leading Indicators to Project Outcome

Subject: Leading Indicator Tool Evaluation

CII Research Team 220, Leading Indicators to Project Outcome, is conducting research through Texas A&M University. The primary purpose of this research is to identify a potential best practice for conducting project reviews during the course of the project. The status of a project is periodically evaluated by traditional methods or standard practices. These methods have indicators that are measured to provide hard data on a project's current status and progress. However, these indicators and their measures may not adequately identify issues that may exist. It may be that current methods lack the ability to provide real time indications of emerging problems that impact project outcomes in a timely manner. A new tool is being developed by Research Team 220 to help meet this need that can measure whether or not a project is "on-the-right-track." The key deliverables of the research team are *Leading Indicators (LIs)* that can be measured in real time to predict project health, and an easy-to-use tool to measure the level of "on-the-right-track" for projects. The tool is being forwarded to you as part of the effort to evaluate the validity of the tool by industry professionals.

We are providing the following package along with this memorandum:

- Leading Indicator Definitions,
- Leading Indicator Tool, and
- Two Evaluation Questionnaires.

Forty-three Leading Indicators are included in the Microsoft® Office Word file. This document provides descriptive material and measurement criteria for each Leading Indicator. The LI tool is a Microsoft® Office Excel file, and it consists of five sections (workbook sheets): introduction, input, two outputs, and a customization feature. The evaluation questionnaires are Microsoft® Office Word files.

There are four steps for the tool evaluation process: 1) selecting projects to be evaluated, 2) understanding Leading Indicator definitions, 3) evaluating projects using the tool, and 4) completing the evaluation questionnaires. Please follow these suggested steps as described below.

Step 1 - participants need to select two projects. **One project** should be **recently completed**. This project should be evaluated in hindsight to help the research team perform statistical tests to determine validity of the LI tool. The **second project** should be a **current project** authorized for design and construction (pre-project planning process successfully completed). This project should be in the detailed design phase and/or less than 50 percent complete with construction. The

current project is required for a real time evaluation of the tool, as the tool is intended to be used in practice.

Step 2 - read the definition of each Leading Indicator until each is understood.

Step 3 - for **current projects**, there are several ways to use the tool: by one evaluator, by more than one evaluator in a group setting, by more than one evaluator with separate evaluations and then aggregating the results. Suggested points in time for project evaluation are when 40 to 60 percent of detailed design is completed and/or when 40 to 60 percent of construction is completed, or select the project phase and percent complete. For **completed projects**, only one evaluator is needed.

Once the decision is made on who and how the evaluation will be performed open the tool and read the given instructions carefully. Read each Leading Indicator and select the appropriate response based on the measurement criteria (comment box in the tool or in the Leading Indicator Definition file). Be sure to save the tool as an identifiable name (e.g. combination of project ID, evaluator ID, and the point of time). Evaluator(s) should review results – dial gauges for project health parameters and by CII Best Practice Groups. The evaluator(s) should assess whether the dial gauges are showing realistic results relative to the overall actual known performance of the project.

Step 4 - complete the appropriate evaluation questionnaire concerning the project and results. Please remember to provide the answer regarding which **weighting option** on the tool output tabs that best describes the project health. The Research Team is gathering input on weights through this evaluation in order to properly calibrate the tool.

Our intent is to have the evaluator complete the tool and the appropriate questionnaire on the computer and return the results (the tool and the questionnaire) to Jiwon Choi, Research Graduate Assistant, at the following e-mail address: **z1choi@tamu.edu** by **February 10, 2005, if possible**. If you have any questions, contact Jiwon at his email address or by phone at (979) 845-6023.

This tool validation process should be completed by someone with a certain level of project experience. The following types of persons are preferred: operation managers, project managers, senior project managers, engineering managers, construction managers, superintendents, project control managers or someone who has an equivalent position and/or experience in project work for both owners and contractors.

We believe that the tool and the questionnaire are user friendly. The Research Team members have performed preliminary tests. These pre-tests show that evaluating the tool requires on average about 90 minutes to complete both tool and questionnaire.

If you have any questions, please contact Stuart Anderson by telephone at (360) 705-6847 or by email at s-anderson5@tamu.edu, Kevin Gierc by telephone at (412) 384-1008 or by email at kjgierc@dickcorp.com, or Paul Ennis by telephone at (412) 675-2576 or by email at pennis@uss.com.

This evaluation is a critical step in the tool development process. Thanks in advance for your help!

Research Team 220
Leading Indicators to Project Outcome
Tool Evaluation
Questionnaires for Completed Projects

Evaluator Information

1. Company Name:
2. Company Characteristic:
   a. ☐ Owner
   b. ☐ Contractor/Engineer/Designer
3. Project ID:
4. Project Location (City or County, State and/or Country):
5. Evaluator:
6. Evaluator's Phone:
7. Evaluator's Fax:
8. Evaluator's e-mail:

Project Characteristic

1. Project Description – Choose a Project Type which best describes the project (check only one)
   a. Heavy Industrial
      i. ☐ Chemical Manufacturing
      ii. ☐ Electrical (Generating)
      iii. ☐ Environmental
      iv. ☐ Metals Refining/Processing
      v. ☐ Mining
      vi. ☐ Natural Gas Processing
      vii. ☐ Oil Exploration/Production
      viii. ☐ Oil Refining
      ix. ☐ Pulp and Paper
      x. ☐ Pipeline
      xi. ☐ Gas Distribution
      xii. ☐ Other Heavy Industrial (Please describe):

   b. Light Industrial
      i. ☐ Automotive Manufacturing
      ii. ☐ Consumer Products Manufacturing
      iii. ☐ Foods
      iv. ☐ Microelectronics Manufacturing
      v. ☐ Office Products Manufacturing
      vi. ☐ Pharmaceutical Manufacturing
      vii. ☐ Pharmaceutical Labs
      viii. ☐ Clean Room (Hi-Tech)
      ix. ☐ Other Light Industrial (Please describe):

c. Buildings
   i. ☐ Communications Center
   ii. ☐ Dormitory/Hotel/Housing/Residential
   iii. ☐ Low rise Office (≤3 floors)
   iv. ☐ High rise Office (>3 floors)
   v. ☐ Hospital
   vi. ☐ Laboratory
   vii. ☐ Maintenance Facilities
   viii. ☐ Parking Garage
   ix. ☐ Physical Fitness Center
   x. ☐ Restaurant/Nightclub
   xi. ☐ Retail Building
   xii. ☐ School
   xiii. ☐ Warehouse
   xiv. ☐ Prison
   xv. ☐ Movie Theatre
   xvi. ☐ Courthouse
   xvii. ☐ Embassy
   xviii. ☐ Other Buildings (Please describe):

d. Infrastructure
   i. ☐ Airport
   ii. ☐ Electrical Distribution
   iii. ☐ Flood Control
   iv. ☐ Highway
   v. ☐ Marine Facilities
   vi. ☐ Navigation
   vii. ☐ Rail
   viii. ☐ Tunneling
   ix. ☐ Water/Wastewater
   x. ☐ Telecom, Wide Area Network
   xi. ☐ Other Infrastructure (Please describe):

2. Project Nature (check only one)
   a. ☐ Grass Roots
   b. ☐ Modernization
   c. ☐ Addition
   d. ☐ Other (Please describe):

3. Project Drivers – Select the primary driver influencing the execution of this project (check only one)
   a. ☐ Cost
   b. ☐ Schedule
   c. ☐ Quality
   d. ☐ Safety
   e. ☐ Stakeholder satisfaction

f. ☐ Other (Please describe):
g. ☐ No primary driver

Project Involvement

Check Project Phase when evaluation is considered and enter approximate percent complete corresponding to when the evaluation is made.

Project Phase		Percent Complete At Time of Evaluation
Detail Design	☐	
Procurement	☐	
Construction	☐	
Total Project	☐	

Project Performance

1. Budgeted and Actual Project Cost by Phase (only include budget and actual cost for Project Phase in which you where involved)

Project Phase	Baseline Budget (Including Contingency)	Actual Phase Cost
Detail Design		
Procurement		
Construction		
Startup		
Total Project		

2. Planned and Actual Project Schedule (only include planned and actual schedule for Project Phase in which you where involved)

Project Phase	Baseline Schedule		Actual Schedule	
	Start mm/dd/yyyy	Stop mm/dd/yyyy	Start mm/dd/yyyy	Stop mm/dd/yyyy
Detail Design				
Procurement				
Construction				
Startup				
Overall Project				

3. How many DART Cases (Days Away, Restricted, or Transferred) were recorded during construction and commissioning? Cases (Note if project was completed before 2003 use lost workday cases)

   How many Recordable Cases were recorded during construction and commissioning? Cases

   What was the total direct field craft workhours for the project?

   Hours

Tool Evaluation

Please address the following questions regarding this application test of the LI Tool

1. Did the LI Tool results agree with your expectations for the evaluation?
   1. If the project was successful did the dial gauges indicate a healthy project at the evaluation point (e.g., green)? Please discuss.

   2. If the project was not as successful did the dial gauges indicate a project that was not healthy at the evaluation point (e.g., yellow or red)? Please discuss.

   3. If the project was not considered healthy do one or more of the best practice outcomes dial gauges indicate which best practice(s) was not healthy at the evaluation point (e.g., yellow or red)? Please discuss.

2. Which weighting option in the outcome tabs best describes your project status?

    1. ☐
    2. ☐
    3. ☐
    4. ☐
    5. ☐

    Please provide any comments on the weighting option you chose.

3. If you had the tool at the time of the evaluation and the tool results indicated a potential problem (e.g., yellow or red dial gauges) would the tool have provided you with sufficient information to identify specific problem areas? Please discuss.

4. How long did it take to complete the evaluation using the tool?

    1. First use 0 hours
    2. Second use 0 hours
    3. Other uses 0 hours

5. Please provide comments on the use of the tool in this specific application knowing that the tool is designed for use in real time.

THANK YOU FOR PARTICIPATING IN THIS EVALUATION.

NOTE: PLEASE RETURN THE EXCEL FILE AND THE COMPLETE QUESTIONNAIRE.

Research Team 220
Leading Indicators to Project Outcome
Tool Evaluation
Questionnaires for Current Projects

Evaluator Information

1. Company Name:
2. Company Characteristic:
   a. ☐ Owner
   b. ☐ Contractor/Engineer/Designer
3. Project ID:
4. Project Location (City or County, State and/or Country):
5. Evaluator:
6. Evaluator's Phone:
7. Evaluator's Fax:
8. Evaluator's e-mail:

Project Characteristic

1. Project Description – Choose a Project Type which best describes the project (check only one)
   a. Heavy Industrial
      i. ☐ Chemical Manufacturing
      ii. ☐ Electrical (Generating)
      iii. ☐ Environmental
      iv. ☐ Metals Refining/Processing
      v. ☐ Mining
      vi. ☐ Natural Gas Processing
      vii. ☐ Oil Exploration/Production
      viii. ☐ Oil Refining
      ix. ☐ Pulp and Paper
      x. ☐ Pipeline
      xi. ☐ Gas Distribution
      xii. ☐ Other Heavy Industrial (Please describe):

   b. Light Industrial
      i. ☐ Automotive Manufacturing
      ii. ☐ Consumer Products Manufacturing
      iii. ☐ Foods
      iv. ☐ Microelectronics Manufacturing
      v. ☐ Office Products Manufacturing
      vi. ☐ Pharmaceutical Manufacturing
      vii. ☐ Pharmaceutical Labs
      viii. ☐ Clean Room (Hi-Tech)
      ix. ☐ Other Light Industrial (Please describe):

c. Buildings
   i. ☐ Communications Center
   ii. ☐ Dormitory/Hotel/Housing/Residential
   iii. ☐ Low rise Office (≤3 floors)
   iv. ☐ High rise Office (>3 floors)
   v. ☐ Hospital
   vi. ☐ Laboratory
   vii. ☐ Maintenance Facilities
   viii. ☐ Parking Garage
   ix. ☐ Physical Fitness Center
   x. ☐ Restaurant/Nightclub
   xi. ☐ Retail Building
   xii. ☐ School
   xiii. ☐ Warehouse
   xiv. ☐ Prison
   xv. ☐ Movie Theatre
   xvi. ☐ Courthouse
   xvii. ☐ Embassy
   xviii. ☐ Other Buildings (Please describe):

d. Infrastructure
   i. ☐ Airport
   ii. ☐ Electrical Distribution
   iii. ☐ Flood Control
   iv. ☐ Highway
   v. ☐ Marine Facilities
   vi. ☐ Navigation
   vii. ☐ Rail
   viii. ☐ Tunneling
   ix. ☐ Water/Wastewater
   x. ☐ Telecom, Wide Area Network
   xi. ☐ Other Infrastructure (Please describe):

2. Project Nature (check only one)
   a. ☐ Grass Roots
   b. ☐ Modernization
   c. ☐ Addition
   d. ☐ Other (Please describe):

3. Project Drivers – Select the primary driver influencing the execution of this project (check only one)
   a. ☐ Cost
   b. ☐ Schedule
   c. ☐ Quality
   d. ☐ Safety
   e. ☐ Stakeholder satisfaction

f. ☐ Other (Please describe):
g. ☐ No primary driver

Project Involvement

Check Project Phase when the evaluation is being conducted and enter approximate percent complete for that phase.

Project Phase		Percent Complete At Time of Evaluation
Detail Design	☐	
Procurement	☐	
Construction	☐	
Total Project	☐	

Project Performance

1. Budgeted and Current Forecasted Project Cost by Phase (only include budget and current forecasted cost for Project Phase in which you where involved)

Project Phase	Baseline Budget (Including Contingency)	Actual Phase Cost
Detail Design		
Procurement		
Construction		
Startup		
Total Project		

2. Planned and Current Forecasted Project Schedule (only include planned and current forecasted schedule for Project Phase in which you where involved)

Project Phase	Baseline Schedule		Actual Schedule	
	Start mm/dd/yyyy	Stop mm/dd/yyyy	Start mm/dd/yyyy	Stop mm/dd/yyyy
Detail Design				
Procurement				
Construction				
Startup				
Overall Project				

3. If the project is under construction, how many DART Cases (Days Away, Restricted, or Transferred) have been recorded to date? Cases

If the project is under construction, how many Recordable Cases have been recorded to date? Cases

What is the estimated total direct field craft workhours for the project?

Hours

Tool Evaluation

Please address the following questions regarding this application test of the Leading Indicator Tool (LI Tool)

1. LI Tool results agree with your expectations for the evaluation
    1. If the project is meeting or exceeding all performance outcomes, does the dial gauges indicate that the project is healthy at the time of evaluation (e.g., green)? Please discuss.

    2. If the project is not meeting one or more of the performance outcomes does the dial gauges indicate that the project is not healthy at the time of evaluation (e.g., yellow or red)? Please discuss.

    3. If the project is not considered healthy do one or more of the best practice outcomes dial gauges indicate which best practice(s) is not healthy at the time of the evaluation (e.g., yellow or red)? Please discuss.

2. Which weighting option in the outcome tabs best describes your project status?
    1. ☐
    2. ☐
    3. ☐
    4. ☐
    5. ☐

    Please provide any comments on the weighting option you chose.

3. If the tool results indicated a potential problem(s) (e.g., yellow or red dial gauges) does the tool provide you with sufficient information to identify the specific problem areas so that you can take actions to resolve the problem(s)? Please discuss.

4. How was the evaluation of the tool conducted?
    1. ☐ Completed by a single individual
    2. ☐ Completed by a group with one response entered
    3. ☐ Completed by separate individuals but aggregated with one response entered
    4. ☐ Other (Please describe):

    Please provide comments on how best to provide input when using the tool.

5. How long did it take to complete the evaluation using the tool?

    1. First use 0 hours
    2. Second use 0 hours
    3. Other uses 0 hours

6. How often would you evaluate project health using the tool?

7. Do you have any suggestions for improving the tool, customizing the tool to better fit your application within your company?

8. Please provide any comments on the use of the tool in this specific application.

THANK YOU FOR PARTICIPATING IN THIS EVALUATION.

NOTE: PLEASE RETURN THE EXCEL FILE AND THE COMPLETE QUESTIONNAIRE.

VITA

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Seoul, Korea 143-816

EDUCATION

M.S.	Civil Engineering	Texas A&M University	May	2007
M.S.	Construction Management	Texas A&M University	August	2004
B.S.	Architecture	Hanyang University	February	1992

WORK EXPERIENCE

Intern	FaulknerUSA, Inc. (Landmark Organization LP), Austin, Texas
	May 2002 - August 2002
	Assisted project manager on a jobsite
Manager	Myoung-In Architects & Engineers Co., Ltd., Seoul, Korea
	September 1996 - July 2001
	Designed commercial buildings in Korea
Self-employed	Chang-In Interior Design & Construction Co., Seoul, Korea
	May 1995 - September 1996
	Designed and built homes and shops
Site-engineer	Sung-Il Construction Co., Ltd., Seoul, Korea
	February 1992 - May 1995
	Built commercial buildings and high-rise apartment buildings

HONORS AND PRIZES

CH 2M Hill Scholarship	The Department of Construction Science (March 2002)
O. N. Mitchell Fellowship	The Department of Construction Science (August 2001)
Employee of the Year	Sung-Il Construction Co., Ltd. (December 1993, 1994)