IMPROVING CONTROL SYSTEM PROJECT SUCCESS WITH FRONT END LOADING RISK ANALYSIS

by

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The endeavor to complete this degree began eighteen years ago while attending graduate night classes at the University of Colorado in Denver. I wish to thank my wife and two sons who supported me during those early years and from 2000 – 2004 while working, traveling and attending night classes at the University of Kansas.

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Executive Summary

IMPROVING CONTROL SYSTEM PROJECT SUCCESS WITH FRONT END LOADING RISK ANALYSIS

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Front End Loading (FEL) has become a recognized and accepted method to improve the performance of process plant upgrade and construction projects. Likewise, FEL also is being used in the control system Industry to improve the outcome of process control projects. Process control system projects utilize newer technologies along with software, construction and communications. These projects frequently present technical challenges and hidden pitfalls when trying to meet project objectives. FEL methods have recently found success in these types of projects by identifying problems early. This paper focuses on FEL applied to Control System Projects. It presents a risk analysis approach to improve the process and demonstrates the application with two case studies.

TABLE OF CONTENTS

List of EXHIBITS .... *Page*

GLOSSARY

(PMBOK Guide, 2000)
(Schuyler, 2001)

Deliverable. Any measurable, tangible, verifiable outcome, result, or item that must be produced to complete a project or part of a project.

Front End Engineering and Design (FEED). The process of planning prior to project execution. Other variations of Front End Loading include Front End Engineering (FEE), Design Basis and Front End Design (FED).

Front End Loading (FEL). The process of planning prior to project execution. An FEL is similar to a FEED but normally includes a final step where management approves remaining phases based on an FEL study return on investment analysis. FEED projects are frequently the planning phase of a project that has already been approved.

Control System. A computer based system used to monitor and control a process control plant. A control system consists of instrumentation, electronic controllers, communication networks and operator workstations.

Control Room. A location within a process control plant that contains operator workstations and controllers.

Controllers. Electronic equipment used to monitor field instrumentation and control end devices such as control valves. Operators monitor and control the plant using workstations communicating to plant controllers.

Decision tree. A graphical representation of a decision problem and the expected value calculations consisting of decision, chance, and terminal nodes connected by branches.

Monte Carlo Simulation. A process for modeling the behavior of a stochastic system by sampling trials values as inputs and repeating the process for many trials. The result is a frequency distribution that approximates the true probability distribution for the system's output.

Opportunity. An uncertain event that has a positive effect on a project' s objectives

Project Risk Management. The systematic process of identifying, analyzing, and responding to project risk. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of events adverse to project objectives.

Project Scope. The work that must be done to deliver a product with the specified features and functions.

Qualitative Risk Analysis. Performing a qualitative analysis of risks and conditions to prioritize their effects on project objectives. It involves assessing the probability and impact of project risk(s) and using methods such as the probability and impact matrix to classify risks into categories of high, moderate, and low for prioritized risk response planning.

Quantitative Risk Analysis. Measuring the probability and consequences of risks and estimating their implications for project objectives. Risks are characterized by probability distributions of possible outcomes. This process uses techniques such as simulation and decision tree analysis

Residual Risk: A risk that remains after risk responses have been implemented

Rework: Action taken to bring a defective or nonconforming item into compliance with requirements or specifications.

Risk. An uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives.

Risk Avoidance. Changing the project plan to eliminate the risk or to protect the project objectives from its impact.

Risk Mitigation. Risk mitigation seeks to reduce the probability and/or impact of a risk below an acceptable threshold.

Risk Event. A discrete occurrence that may affect the project for better or worse.

Risk Response Planning. Developing procedures and techniques to enhance opportunities and reduce threats to the project's objectives.

Threat. An uncertain event that has a negative effect on a project's objectives

Workaround. A response to a negative risk event. Distinguished from contingency in that a workaround is not planned in advance of the risk event.

Chapter 1

INTRODUCTION

FRONT END LOADING AND PROJECT RISK ANALYSIS

Much has been written about Front End Loading (FEL) and Project Risk Analysis as applied to large construction projects. The benefits of utilizing FEL and Risk Analysis in Projects are well established in research and project case studies. Over the past 30 years, three organizations have contributed to basis behind this body of knowledge; the Project Management Institute (PMI), the Construction Industry Institute (CII) and Independent Project Analysis, Inc. (IPA).

Publications from PMI, CII and IPA generally treat project risk analysis and Front End Loading as two separate topics with some correlation. Not much has been developed that show how the two concepts are closely related.

In addition, Control System Projects tend to have characteristics that differ from construction-type projects. A Control System Project will usually employ new technologies, software design and disciplines not common in the construction industry. The higher risk from new and challenging technologies support the importance of including risk analysis in the FEL portion of a project.

THE IMPORTANCE OF IMPROVING THE PROJECT PROCESS

Recently, the business community has realized the importance of project cost overruns. Successful businesses select capital projects based on the expected return. Those projects that generate the highest expected return contribute the highest returns to the business. In the past, project cost estimates were assumed accurate with a perceived margin of error. In reality, many projects are over budget and over schedule with huge losses outside the initial expected budget and contingency.

Clients, contractors and engineering companies have struggled to maintain budgets on large complicated projects. Of fourteen "Mega-Projects" in the last 20 years, IPA reported that the average over-run was 46% or $11.8Billion. Seven of the fourteen projects were considered financial failures with over 40% over-runs for each. Only two of the fourteen were completed under budget. Project schedule results were also poor. Six projects slipped in schedule by more than 20%. The average schedule slippage for all 14 projects was 28%. Only three of the fourteen projects are viewed as successful. (Merrow 2000) (Merrow 2003)

Based on project case studies, both IPA and CII report that poor scope definition as a major reason for project cost over-runs and schedule delays. Both organizations also support the idea of changing the traditional way of executing projects and promote procedures such as FEL to reduce schedule and cost overruns. (Batavia 2001). Likewise, past projects have shown that integrating the owner's team with the engineering firm during the FEL study is critical to the project success (Avidan 2001)

Considering the amount of capital lost due to project issues, many now recognize the need and importance to improve the project management and implementation process.

FIELD PROJECT REPORT OBJECTIVE

The objective of this paper is to show how the combined effect of FEL and project risk analysis can lead to a successful control system project. It ties the

FEL and project risk analysis concepts together as applied to the control system industry. The basis and selection of control system case studies are from the author's project experience in Control System Projects for Chemical, Pharmaceutical, Power and Petroleum industries. The author is currently including risk analysis and FEL techniques within control system projects with positive results. Once such case study is examined in later chapters. These concepts continue to be fine-tuned through project successes and "lessons-learned".

A project is successful when it meets the original scope, budget and schedule defined at the time of business funding.

Chapter 2

PROFESSIONAL ORGANIZATION AND LITERATURE RESOURCE REVIEW

BACKGROUND

Advances have been made in the recent years to improve the project management process. This has resulted in new publications, books, seminars, product offerings and analysis of past projects. The development of project procedures, processes and body of knowledge continue to evolve. The resources used for this paper include publications, seminar presentations, web sites, textbooks, case studies and the author's own case-study experience. Many professional organizations promote and facilitate publication on project management topics. Relative to the topics of this paper, three key organizations are described below:

PROJECT PROFESSIONAL ORGANIZATIONS

Project Management Institute (PMI)

PMI was established in 1969 outside Philadelphia. It is the primary non-profit project management professional organization. As an indication of the growth and interest in project processes, PMI's membership was only 8,500 in 1990. There are now more than 100,000 member worldwide representing 125 companies. PMI offers project research, publications, training, certification and standards. After 1990, a set of publications was developed to standardize project procedures. This later became *A Guide to the Project Management Body of Knowledge (PMBOK Guide), Version 1.3, 2000 Edition (ANSI Standard ANSI/PMI 99-001-*

2000). This paper is based on this guide covering project risk, scope, cost and schedule management processes. (PMI, 2004)

Construction Industry Institute (CII)

The Construction Industry Institute is a consortium of owners, engineering contractors and suppliers and established in 1983. The CII was formed due to the recognition of project problems in the construction industry. Prior to 1983, the Business Roundtable had conducted a five-year study of construction project problems with over 200 recommendations. Formation of an organization to improve project planning and project execution was one of the 200 recommendations. CII was created to address this need. CII provides a series of publications as part of *Best Practices for the Construction Industry.* The publications organized in 13 categories including (1)Front-End Planning, (2)Design, (3)Procurement, (4)Construction, (5)Startup & Operations, (6)People, (7)Organization, (8)Project Successes, (9)Project Controls, (10)Contracts, (11)Safety, Health, and Environment, (12)Information, Technology Systems and (12)Globalization Issues. Publications are available to member organizations or can be purchased through the CII website, http://construction-institute.org. (CII, 2004)

Independent Project Analysis, Inc. (IPA)

IPA provides consulting, evaluation and analysis services for end users seeking to improve project performance. IPA is in a unique position of collecting project database information for research and project analysis. As a result, IPA offers statistical tools and benchmarks to measure and evaluate project performance. IPA was founded in 1987 and currently includes a staff of 80 project analysis professionals. IPA frequently presents findings at seminars based on a database of over 2000 past projects. Edward Merrow, President of IPA, presented findings at the 32nd Annual 2000 Engineering and Construction Contractor's

Conference (ECC), Colorado Springs, CO regarding the value of FEL for smaller projects (less than $5Million). IPA presented similar information at the August 20, 2003 ACES Mini Seminar in Perth. (Merrow, 2003)

OTHER LITERATURE

A general literature search was performed through the University of Kansas online library catalogue and Internet searches were conducted using search engines, Yahoo, Google and MSN. The references used for this report are listed in the bibliography. The Web-based searches generated companies, such as Integraph, which is implementing FEL in their product line and engineering companies, such as Bechtel, that are providing FEL services. Recent texts available through PMI also reference FEL and Risk Management. These are included in the bibliography. *Risk and Decision Analysis in Projects* by John Schuler is a compilation of 18 articles in PMI's professional monthly magazine, *PM Network*. References to actual project case studies outside the author's experience are from *Project Management Casebook* published in 1998 by PMI.

PROCEDURE AND METHODOLOGY

LITERATURE SEARCH

The literature search was performed to determine the current state of knowledge in the field of Project Front End Loading and risk analysis. Because of recent advances in this field, some of the information is from recent seminars and actual case studies. The literature search established a framework of current thought on Front End Loading procedures and Project Risk Analysis when applied to actual applications.

CASE STUDY ANALYSIS

The author has provided engineering services for US and International control system projects over the last 25 years. Most of the experience was in the Petrochemical industry with control projects ranging up $50Million. During the last 10 years, the author has managed several projects for chemical, refining, power and pharmaceutical industries. Some of these projects utilized FEL and Risk Analysis while others were direct design with little planning. Specific benefits of Front End Loading processes and risk analysis are investigated with two projects completed over the last three years.

The current state of Front End Loading and project risk analysis in the control system industry are compared to the author's own practical experience. Front End Loading methods, risk analysis methods and experience are used to develop a set of success factors during project planning stages. This paper presents recommendations for future Control System Project planning and analysis along with recommendations for future work and study.

Chapter 4

FRONT END LOADING

Project Planning

On March 5, 1991, Bechtel project management personnel arrived in Kuwait three days after allied troops had moved through Kuwait City. The immediate purpose was to organize and manage the Al-Awanda project needed to extinguish 647 oil well fires. The much larger and longer-term project was established to plan and organize infrastructure rebuilding required as a result of the 1991 Gulf War.

The results of this project are staggering. Over a 2-year period from March 1991 to June 1993, 5 Million project management and engineering man-hours were spent. Field labor hours were over 50 Million. This remarkable project required 16,000 workers from thirty-six countries. The project success began with planning and organization. Plans were required to scope, schedule, budget and execute the work. A master back to front schedule was developed with nine subproject work breakdown structures. Planning teams surveyed every oil field, production and export facility in order to determine scope, cost schedules and execution plan. Despite the challenges, the project met the key objective of resuming oil production in 1993. The success was due to planning (Cleland et al., 1998)

As stated in the Introduction, IPA and CII report poor project scope definition as the main contributing factor behind project cost overruns and schedule delays. To avert such problems, project teams have recognized the need to perform planning prior to project execution. Good, thorough planning by experienced individuals is required. Planning and scope definition does not guarantee project success if the planning is inadequate and resulting scope definition is poor. (Merrow, 2000) (Batavia, 2001)

Efforts in recent years have focused on improving the planning process. Project planning phases have different terms unique to a specific end user, engineering firm or industry. The documents and cost estimates completed during this work also vary between projects and clients.

Development of the Project Life Cycle

The early texts on project management defined the "Project Life Cycle" as a basis for defining the project sequence and structure. The first formal textbook published by PMI in 1976, "Managing High-Technology Programs and Projects" defined seven project steps; start, concept, definition, design, manufacture, installation and termination (Wideman, 2004).

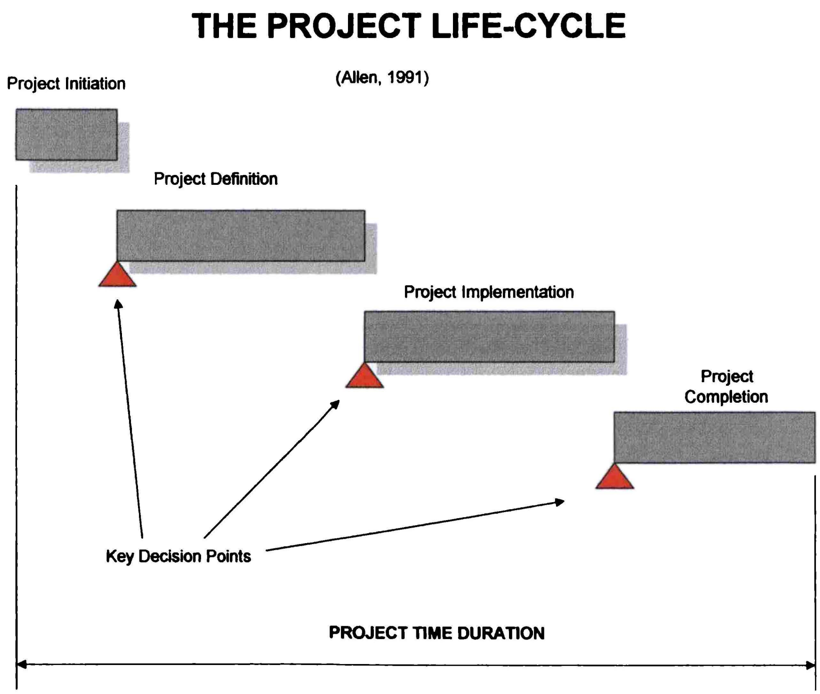
Throughout the 70's and 80's, several variations of the project life cycle were published. The project life cycle concept remained with different terms and phrases. In 1990, "Dimensions of Project Management", further established the project with inputs and outputs (e.g., deliverables, final state, construction). This model simplified the project life cycle to four generic phases that also apply to problem solving: (Patzak, 1990)

- Objectives Definition Phase (What is to be accomplished?)
- Design Phase (How is it to be accomplished)
- Realization Phase (Actually doing the work)
- Implementation Phase (Handover of results)

During this period, there were interesting developments that gained insight into the success of capital project. Wideman presents these concepts below: (Wideman, 2004)

- Decision points were added between phases to establish whether the project should proceed or not. These points are referred to as control points, gates or gating (Exhibit I).
- The phases were isolated in quantum groups separated by the control points. This was different from previous models that emphasized overlapping and interaction between phases.

EXHIBIT I: THE PROJECT LIFE CYCLE (Allen, 1991)



Utilizing decision points became a precursor to the FEL process that is now used by several companies. The second major development was to recognize the importance of the initial project planning phases. Wideman highlights publications by individuals that noted the importance of up-front planning. Perhaps the best reflection of this development is that quoted from Dr. P. W. G. Morris. (Morris, 1998, 5)

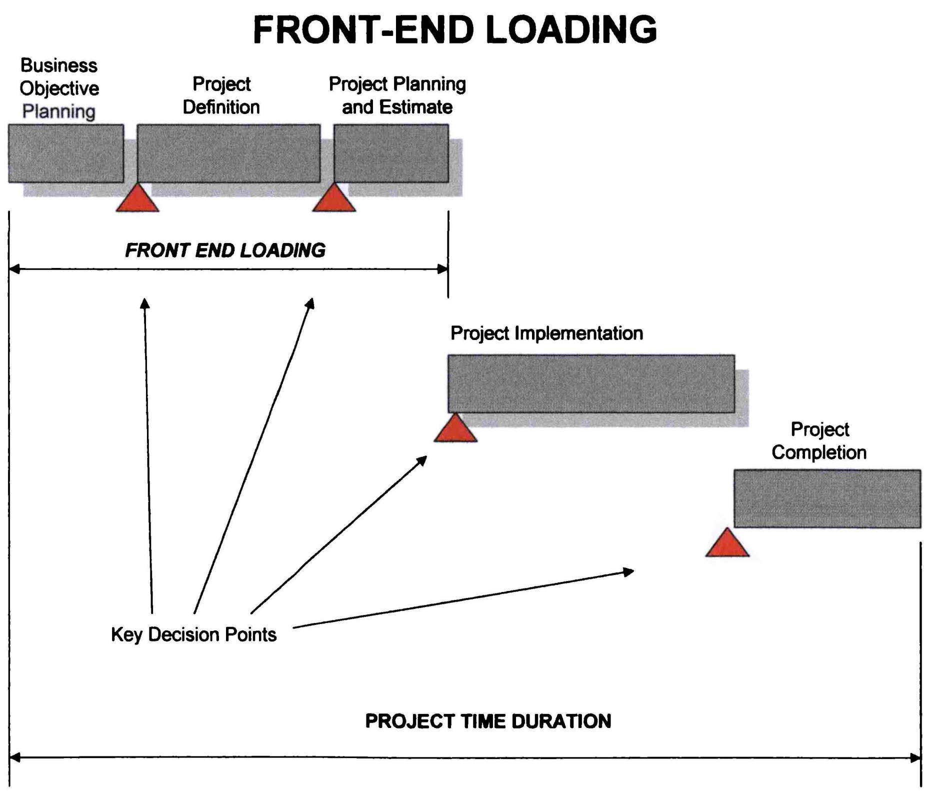
"Too many people see project management as beginning when the project is set up. Yet all the lessons of modern management, and indeed all the lessons of project management history, show that time spent up front in defining needs, exploring options, modeling, testing, and looking at different business benefits is central to producing a successful project. The decisions made at the early definitions stages set the strategic framework within which the project will subsequently develop. Get it wrong here, and the project will be wrong for a long time, perhaps forever. Get it right, and you are half way there. (Defining the problem is half the solution; 90 percent of the outcome is defined in the first 10 percent of the project.) This is one of the most crucial areas of project management professional input."

Emphasizing the planning process associated with decision points has developed into the Front-End Loading process during the later half of the 90s. Several companies such as Shell, Dupont and Chevron have adopted Front-End Loading to improve their business results and report the success this has generated to their profitability (Sullivan, 1998)

What is Project Front End Loading?

Project Front End Loading is a project planning process prior to project execution and construction. FEL and FEED are used interchangeably to refer to up-front planning. However, the FEL term used by IPA and adopted by many companies is also a process to select projects (Hollmann, 2002). Exhibit II depicts a typical project using an FEL process.

EXHIBIT II: THE FRONT-END LOADING PROCESS



The FEL Phase is normally broken into three sub-phases, business objective planning, project definition and project planning/estimation. The actual work conducted will vary within the three following categories (Sullivan, 1998)

- Business Objective Planning: The businesses goals to be pursued are framed and aligned with the company objectives

- Project Definition: Project alternatives are reviewed to meet the business objectives

- Project Planning: The alternative selected is further defined, estimated and developed sufficient to begin detailed design. Estimates are developed to accurately evaluate the project profitability.

Front End Loading will prepare a project for success through planning. The results of such a project determine the cost and schedule necessary to understand the project's internal rate of return (IRR). IRR and similar measures are used to determine whether a project should be selected or rejected based on business merit.

According to Hollmann (2002), a simplified version of IRR follows:

Internal Rate of Return (IRR) = [(Project Revenue Present Value) – (Project Present Value Cost)]/[Value of Capital Investment]

From this equation, a problem project with high project capital costs over a sustained period of time could virtually eliminate the expected return on a project. The problem is usually not realized until it is too late with little option but to either move forward or stop work and recognize losses. A well-conducted FEL will avoid the situation beforehand. If initial planning cost estimates are inaccurate, not only may the selected project be unprofitable, but other profitable projects could be incorrectly screened through the selection project. With poor planning, there is a double loss; high cost over-runs and missed opportunities.

Front End Loading for Control System Projects

The FEL process applies to control system projects like any other engineering project. The purpose of FEL is to define the schedule, scope and budget for the design and execution of the project. The budget (cost) and schedule will assist in the screening and selection of profitable projects. Accurate scope definition addresses the major flaw behind most project failures reported by CII (Batavia, 2001). A set of deliverables is generated during the FEL sufficient to accurately define the project costs and scope. Once the FEL is completed, the true profitability of the project may be determined and the likelihood for success is improved.

Control system projects frequently use new computer, communication and software technologies. An intangible benefit of the FEL is the knowledge gained in applying newer technologies. The may strengthen the company's competitive ability to compete, or win the final contract.

As discussed in later chapters, risk is an important aspect of control system projects. Control System Projects tend to present increased risk due to newer and challenging technologies involved. Unless the planning is done correctly and risk considered correctly, scope, cost estimates and scheduled developed during the planning stages may be inaccurate. The correct deliverables and proper assessment of risk can avert schedule delays and budget overruns.

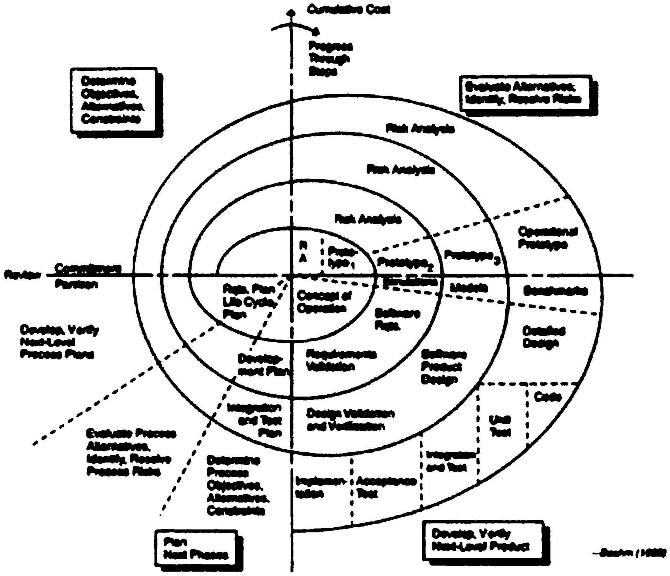
Control System Software Considerations

Control system projects contain a mix of systems, communications and software projects. Although many of the same techniques and tools are used to manage projects, software project management presents unique challenges. Several life cycle models have been presented. One common model is the spiral model (Exhibit III) discussed by Boehm and highlighted by Wideman (2004).

Under the Spiral model, the software begins at the center origin and progresses outward through each of the following quadrants:

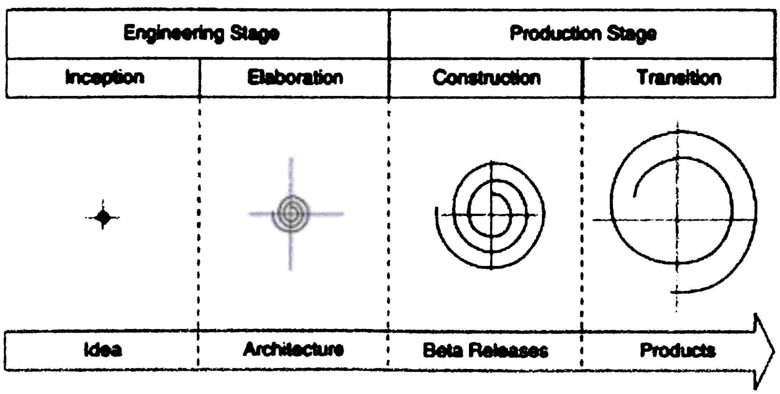
- Quadrant 1: Determine objectives, alternatives, constraints
- Quadrant 2: Evaluate and identify risks
- Quadrant 3: Develop the next level product
- Quadrant 4: Plan the scope and execution for the next phase

EXHIBIT III: TYPCIAL SOFTWARE SPIRAL MODEL (Wideman, 2004)



Walker Royce further bridged the Spiral Model with the linear models presented earlier by grouping iterations within Inception, Elaboration, Construction and Transition (Royce, 1998). Under this model, Inception is similar to the FEL phase where risks and problems are first identified.

EXHIBIT IV: PROJECT LIFE CYCLE USING THE SPIRAL MODEL (Royce, 1998)



The spiral model provides better software risk management and produces a system that is responsive to client needs. However, when packaged within an overall life cycle project with milestone deliverables and gates, the spiral model may be difficult to manage due to the iterations that do not quite fit the milestone deliverables. Control system projects on high capital-intensive projects such as refiners and chemical plants do not have the flexibility to expand or delay the schedule to refine software applications. Many of the early computer controls installed in plants were plagued with schedule problems due to the early application lower level programming. These delayed projects were quire costly to owners and contractors. As programming tools and technologies evolved, many control systems now us utilize higher-level languages incorporating efficient and accurate configuration. The software risks still exist but have been greatly reduced through improved programming tools and user interfaces.

Control system projects recognize the need for software iteration and use a variation of the spiral model to create intermediate software deliverables that are tested within a milestone framework. The iteration is done by developing code and conducting intermediate tests. A typical control system project will conduct in-house tests, a client factory acceptance test, a site acceptance test following system commissioning and a performance test during startup. The type and frequency of testing is determined during the FEL phase of the project. The FEL also define many of the requirements (such as operator interface requirements and number of instruments monitored) so that impact on software is minimized in later stages of the project. A project with newer software technologies or identified risks will likely need to conduct more frequent and thorough tests.

Chapter 5

CONTROL SYSTEM PROJECT DESCRIPTION

CONTROL SYSTEM PROJECT OVERVIEW

The type of projects considered is based on the author's experience. The systems are normally computer based and used to automate the control of a refinery, chemical plant, power or other type of industrial facility. Frequently, the control system project is part of a larger project to build the plant or infrastructure.

Control Systems in the continuous process control industries consist of the following (Liptak, 2002):

- Instruments, control valves, analyzers and other end devices to monitor and control actual process materials (typically flow, level and temperature)

- Field wiring between end devices and input/output circuit cards. The signals are either current/voltage signals or new bus technologies.

- Input/Output equipment that convert analog or Fieldbus communication to digital information

- Communication networks between Input/Output equipment and computer workstations used by plant engineers and operators to control the plant

- Operator Workstations that display plant process variables and provide a means for the operator to control and monitor plant operation

- Communication interface to business level computers and information.

Exhibit V shows a typical control system. For large plant, most of the control system and workstations are centralized in a single main plant control room where plant operators monitor and control plant processes (Exhibit VI). Instrumentation in the plant to measure variables such as flow, level and temperature are wired back to the control room as analog signals (Exhibit VII). Recently, new systems are using Foundation Fieldbus digital communication between the control room and plant instrumentation.

A control system project in a process plant normally includes the types of equipment listed above. The scope of every project is different. It is important to note these differences and customized planning required. For upgrades or new plants, experienced engineers and project managers realize the dangers of re-using plans from previous projects and assuming that site conditions are similar.

The types of projects covered by this paper pertain to control system upgrades. An upgrade project requires updating or replacing an existing system with a newer system. FEL Studies during upgrade projects are needed to uncover problems that may not be apparent until later stages of the project. The condition of existing software and electrical documentation can drastically affect the project success as seen in the case studies presented later.

This does not mean that FEL Studies for new plants have less benefit. Many companies use FEL procedures for both new and upgrade projects with successful results.

EXHIBIT V: TYPICAL CONTROL SYSTEM ARCHITECURE

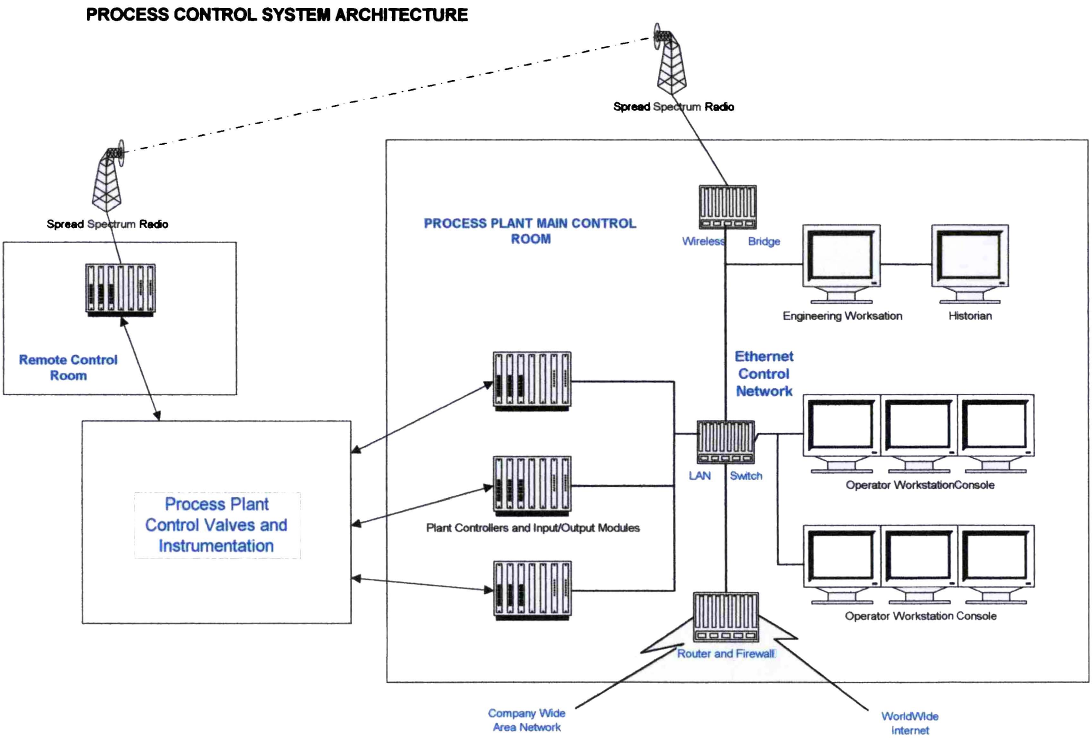
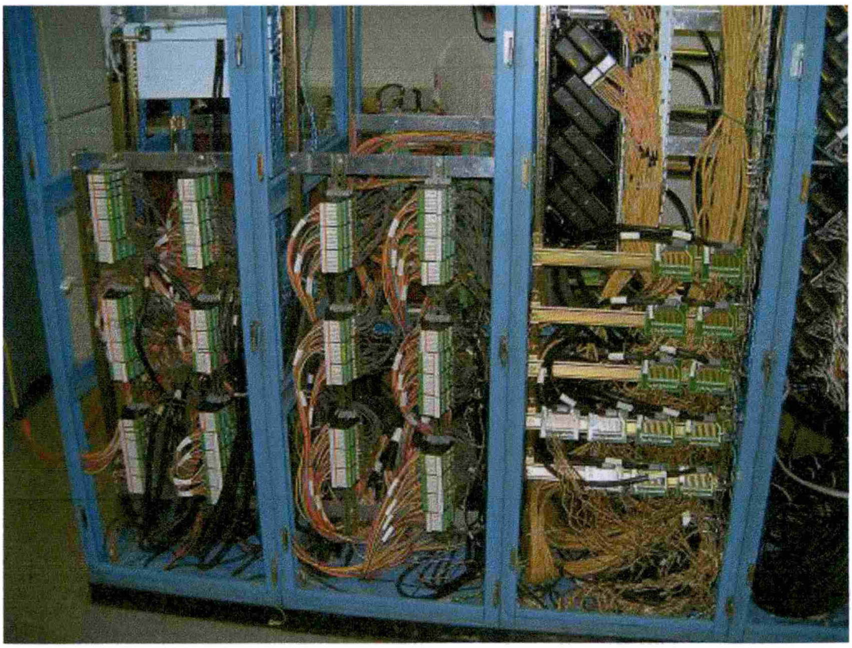


EXHIBIT VI. OPERATOR CONTROL ROOM AND WORKSTATIONS

EXHIBIT VII. CONTROL SYSTEM CONTROLLERS AND WIRING



C h a p t e r 6

CONTROL SYSTEM PROJECT CASE STUDIES

CASE STUDY I:

Chemical Plant Control System Upgrade Project with Front End Loading

In December 2000, a chemical company sought bids from engineering firms for upgrading a control system used in the manufacture of a type of plastic. The schedule required completion of the upgrade in May 1, 2001. The scheduled mechanical maintenance of the process unit established the end date. Because the owner would face fines from customers if production were delayed, the project contract stipulated liquidated damages for any delays caused by the engineering firm. .

The owner was presented with a project plan that included Front End Loading. However, the client believed the fast track schedule presented allowed very little time for any upfront work. The client decision preferred to begin detailed design immediately.

The project presented several challenges. The following are a list of key problems that occurred during the course of the project:

- In order to implement software code quickly, the programming team decided to replicate the software without trying to clean up any of the existing code. During design development, many patches and abandoned lines of code were found. The existing software had been maintained over a 15-year period with very little documentation. Consequently, the purpose of much of code was not clear. The impact this had on the new software platform created significant concern among system programmers. Due to time constraints, all of the code was blindly implemented in the new system. Testing required considerable rework to determine the purpose and need for the software patches.

- New instrument and communication cables needed to be installed in the existing control room under raised floors. During construction and following removal of equipment, it was found that much of the space needed under the floor was unavailable. Engineering drawings had already been completed that showed routing of cable under the floor. In order to continue, a re-design was required to re-route cables above the ceiling. Changes late in the project created additional material, construction and engineering costs not in the original project budget.

- Outside the control room, control instrumentation is located in hazardous areas as defined under National Electric Code requirements (Class I, Division II). This type of area indicates that flammable vapors may be present. An electrical spark could ignite vapors and energy must be limited or equipment must be installed in boxes certified as explosion-proof. The owner's installed equipment uses intrinsic barrier terminals to limit the energy on all instrument wiring that exits into the hazardous area. The barriers are diodes that shut excessive current to ground in the event of a short circuit. During design, the design team found that existing older style barrier terminals did not interface correctly with the new control system. This required replacement of many of the barrier terminals. Additional time, schedule and cost were needed.

- During installation of the new system, the actual signal and safety ground in the control room were found different from plant drawings. Re-design of the ground system was required.

Other problems were noted during the project and are listed in Exhibit X. These items are shown as risks that were realized during the project. Fortunately for the engineering firm, the owner needed to delay the maintenance schedule and the overall project startup was delayed until July. No liquidated damages were incurred.

All of the problems during the course of the project would have been discovered early had the project implemented a short Front End Loading study. The advantage of finding problems early is that time and resources are saved. Front End Loading would have discovered the space problems with the raised floor before detailed engineering and construction. Even though problems found during the FEL would still have been a concern, there would have been less engineering rework and less impact on construction. Both time and cost would have been saved.

The project was $125,000 over-budget and most of this cost was due to engineering, programming and construction re-work during later stages in the project. Had the owner not delayed the project, there may have been additional liquidated damages due to schedule delays.

CASE STUDY II:

Cogeneration Plant Control Systems Upgrade Project with Front End Loading

In the fall of 2001, the owner of a Cogeneration Plant requested assistance with upgrading an outdated control system. The older control system was becoming expensive to maintain as replacement part costs were increasing. The owner was aware of potential design problems and was supportive of the Front End Loading concept.

During the Front End Loading work, several problems were identified. Plans were made to work around the problems saving time and budget resources. The key design issues are noted below:

- Electrical and instrument cables entered control cabinets through a second story concrete floor. Once inside the cabinets, the cables were found to route through spaces between the cabinets. In some cases, the cables were intertwined with other cables. The cables were also unlabeled. The design approach prior to FEL was to un-terminate the cables, remove all the cabinets and re-terminate the cables in new control cabinets. Following FEL, this design approach was changed. The cabinets were left in place, cables un-terminated and the control equipment was removed from the existing cabinets. New control equipment was then installed in the cabinets and cables were terminated.

- A one-mile data communication link between the Cogeneration plant and a chemical plant was to be replaced with new fiber optic cable. Further examination found significant maintenance problems with this link due to hot steam lines near communication cables. The distance could be increased along the route except for underground sections that ran under public highways. The cost of installing the new fiber cable was expensive and cable degradation of the cable would occur due to the heat. During the FEL phase, wireless data communication using spread spectrum radio was investigated and found to be a cost-effective alternative. Redundant Cisco wireless bridges were installed between the two sites.

These and other identified risks are shown in Exhibit XI. Had these problems not been identified early in the project, significant problems would have developed later in the project. Similar to the Case I project, these problems would have certainly created schedule delays if uncovered late in the project. A Front End Loading Project will frequently identify such problems so the project team can determine an appropriate response.. Such results appear in the statistics that IPA reports mentioned earlier. Projects that have FEL activities tend to be more successful (Merrow, 2003)

This is where risk analysis can provide a significant role in improving the FEL process. Once risks are identified in a project, a qualitative risk analysis can then be used to evaluate the impact on the project and determine the appropriate response determined by the FEL team.

Chapter 7

IMPROVING FRONT END LOADING THROUGH RISK ANALYSIS

Defining and Identifying Risk

The most important analysis step is to correctly identify and understand the risks on a project. If the risk is not understood correctly or overlooked, the resulting problems during later stages of the project may overshadow all other risk planning.

Risk has several definitions and depends on the applications. Risk planning manuals may customize the definition to fit a specific application. From a project management perspective, risk is defined as "an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives" (PMBOK Guide, 2000, 20).

Similarly, Schuyler defines risk as "the quality of a system that relates to the possibility of different outcomes" (Schuyler, 2001, 6). The discussion by Schuler further classifies risks as "threats" or "opportunities". This is inline with SWOT analysis, which classifies events by Strengths, Weaknesses, Opportunities and Threats. During the FEL process, project threats and opportunities are identified. All of these are risks. The goal of the FEL process is to reduce the chance and impact of a threat and increase the chance and impact of an opportunity.

Current Front End Loading practices do not necessarily include any type of formal risk assessment. These studies frequently present initial documents based on site surveys and may not specifically identify and evaluate the impact risk events will have on the project. As seen from the control system project case studies, the FEL process identified potential problem areas and planned the project accordingly. By taking action early, this averted discovery in later project stages when action would more cost and schedule impact.

This paper proposes improving the FEL process by improving the risk assessment that is done in the FEL Study.

Risk Assessment Steps

Several tools and methods have been developed to conduct risk planning and assessment. Based on the case studies presented, risk analysis techniques (Githens, 2001) (PMBOK Guide, 2000) (Caltrans, 2003) (Kindinger, 2000) and experience with successful control system project, the following risk analysis steps should be included in the FEL study.

STEP 1: IDENTIFY THE INITIAL PROJECT SCOPE

The project scope and execution is usually defined during the proposal stage of the project. This establishes a basis for the project. If no scope has been identified, some definition should be established to develop the initial work boundaries and scope of the site survey.

STEP 2: IDENTIFY THE FEL TEAM

As stated early, it is important to identify the risks early in a project. This activity requires competent and experienced individuals. Frequently, risks are identified based on experience and past projects. It is important that the FEL team be experienced. It is possible to utilize a less experienced staff. The type of project may offer technical challenges that are new to the industry. The team needs to recognize the additional risk due to inexperience and should try to compensate by consulting with experienced peers, additional testing or conducting pilot project or prototypes. The team usually consists of the project manager and technical leads that will execute the project. The lead individuals normally have some control system experience

STEP 3: SURVEY THE PROJECT SITE

For control system upgrade projects, a good FEL project will investigate potential problems at the site. All successful upgrade projects include initial site work. As noted earlier, the massive Kuwait Infrastructure project started with a planning team that surveyed every damaged location and facility. The information gathering requires reviewing drawings and comparing drawings to actual site conditions. The condition and accuracy of drawings significantly affects the overall cost and schedule for an upgrade project. The client personnel who operate and maintain the system should be interviewed. Many times, problems are undocumented but known by those familiar with the specific location and systems.

STEP 4: IDENTIFY RISKS

Technical risks are identified during the site survey. Checklists are useful to make sure problems discovered on past projects are investigated. Other types of risks may be uncovered by interviewing various divisions in the client organization. At the end of the site survey, the project team should review results and determine the risks identified for the project. This resulting risk list should include opportunities as well as threats to project scope, schedule or budget. Triggers also need to be identified where appropriate. A trigger is a warning event that a risk is likely to occur. For example, if weather is identified as a risk to construction activities, weather forecasts become triggers to indicate whether the event is about to occur. It may be necessary to consult with outside specialists if a threat or opportunity is outside the team's specialty. Hazardous materials such as asbestos may require special handling. Newer technologies involving wireless communication may offer cost opportunities and require further site studies to determine feasibility.

STEP 5: QUALITATIVE RISK ANALYSIS

Qualitative risk analysis is an evaluation of the probability and impact of each identified risk. This analysis will score and rank each risk based on the tools presented later in this chapter. The ranking and score allow the project team to develop an appropriate response plan. Qualitative risk tools found useful for control system projects are presented later in this chapter.

STEP 6: QUANTITATIVE RISK ANALYSIS

Quantitative risk analysis estimates the probability of each risk using statistical methods. This is frequently done with software simulation using Monte Carlo or Latin Hypercube simulation techniques. Decision Tree Analysis can be utilized for alternative project plans. For control system projects, simulation may assist in determining appropriate budget and schedule contingencies. One weakness is that analysis requires accurate historical cost and budget data to be useful. Cost estimating requires a known distribution with mean and standard deviation data. Additional resources are required to establish this information and conduct the simulation. The FEL team needs to determine if quantitative risk analysis is required for the project. For control system studies, these techniques may be very useful for high-risk projects where the additional resources are justified.

STEP 7: RISK RESPONSE PLANNING

Once risks have been identified and ranked, the FEL will need to develop a plan to determine the appropriate response to take. Each risk requires a review of the appropriate action. Generally, response falls within the following categories (Caltrans Project Risk Management Handbook, 2003, 12):

- Avoidance: The project plan is changed to avoid the risk completely. Avoidance has less impact if done early. A prime benefit of the FEL study is that it allows changes in project plans without adversely effecting project objectives. Schedules, engineering design plans and types or resources may be changed before any project costs are incurred. Avoidance may actual reduce project costs/durations and thereby provide opportunity.

- Transference: The risk is transferred to another party. This is normally done contractually or by mutual agreement among the project participants. For control system projects, transference applies when highly technical or specialized areas require expertise familiar with the risk. Dealing with hazardous materials requires brining in the proper experience and resources. Removing asbestos tiles from an existing control room floor is an example where transference applies

- Mitigation. Mitigation is to reduce the risk impact or probability .Action may be taken to re-focus resources, establish schedule triggers or implementing engineering studies.

- Acceptance. Acceptance may mean no action is taken. In that case, the project team will be required to deal with the event if it occurs. A contingency plan may be in place to deal with the event if it occurs. Risks that have very little probability of occurring may not justify the additional resources required. In that case, the FEL team may decide to accept the risk without changing plans.

Risk planning requires the schedule, budget and organization be structured in light of new risks uncovered during the site survey. Triggers should be identified in the project so that early warning signs indicate when a project is being exposed to risk. The FEL study should revise the project plan accordingly (PMBOK Guide, 2000)

STEP 8: RISK MONITORING

A trigger is much like a smoke alarm in home. Smoke alarms are placed in locations where trouble and smoke will first be detected. Early warning will allow a response that reduces the potential fire damage. Project triggers should be established within the project in high-risk areas. If electrical wiring is identified as a high-risk area on a project, then more communication with the electrical design team may be an appropriate way to keep track of missed deliverable dates or problems the team is having. Project schedules should establish milestone events that indicate triggers. A missed or delayed milestone could trigger that an impending risk is likely.

Risk monitoring will require re-evaluation of project plans, contingencies and risks. The risk plans need to be included in design reviews and throughout the life of the projects. New risks may be discovered and require an appropriate response.

Qualitative Risk Analysis Tools

Two case studies were presented previously. One project included an FEL study and the other bypassed the FEL process. The outcome of the FEL project was more successful and correlates to studies by IPA. The proposed qualitative tools are presented along with application to the control system project case studies. To demonstrate this, risk analysis tools are presented and applied to the two case studies. The outcome is a much better understanding of each risk event and response required by the project team

In *A Guide to the Project Management Body of Knowledge* (PMI, 2000), two techniques are presented for evaluating and ranking risks. Ranking these risks will allow the project team to address serious risks to the project and allocate resources appropriately. Exhibit VIII is a table that evaluates risk impacts by project objective.

At this point, it is worth noting the high financial risk that many projects face. A pubic works or government cost-plus-fee project may only realize 5% gross profit. For a $1 Million project, the expected gross profit is only $50,000. Therefore, a $50,000 or 5% overrun on the project will eliminate all of the project profitability for the engineering firm. One unforeseen construction change can easily cost this much. When evaluating the potential impact an event has, the engineering firm will need to evaluate risk based on the profitability of the project. PMI (PMBOK, 2000) provides a general guide for identifying cost relative to the entire project cost. However, it is up to the project team or engineering firm to quantify the impact that changes and risks have on the project.

For this paper and case studies presented, the cost impacts are ranked relative to the project profitability rather than the overall project budget. A cost change that affects the profit by 20% or more would be a high impact event.

EXHIBIT VIII. Evaluating Risk Impact on Project Objectives (Based on PMBOK Guide, 2000, 136)

Project Objective Score	**Very Low Impact (.05)**	**Low Impact (0.1)**	**Moderate Impact (.2)**	**High Impact (.4)**	**Very High Impact (.8)**
Cost	Insignificant Cost Increase	<5% Cost Increase	5-10% Cost Increase	10 – 20% Cost Increase	> 20% Cost Increase
Schedule	Insignificant Schedule Slippage	Schedule Slippage < 5%	Overall Project Slippage 5-10%	Overall Project Slippage 10-20%	Overall Project Schedule Slips>20%
Scope	Scope Change Barely Noticeable	Minor Areas of Scope Are Affected	Major Areas of Scope Are Affected	Scope Change Unacceptable to the Client or Budget	Project End Item Effectively Useless or >20% Scope
Quality	Quality Degradation Barely Noticeable	Only Demanding Applications Are Affected	Quality Reduction Requires Client Approval	Quality Reduction Unacceptable to the Client	Project End Item is Effectively Unusable

The table in Exhibit VIII uses a non-linear cardinal scale to rank the risk impact on a project. These scales can be modified as needed by the project team to fit the specific application. An ordinal scale does not use a number system but uses ranking based on "very low to very high" or "good to worst", etc.

Once impact has been identified, a **Risk Score** can be used to rank the risk according to the probability and impact on the project. The Risk Score is the product of these two variables:

Risk Score = Probability x Impact Score

Where:

Probability = 0 – 1.0 with 1 representing 100% probability of the event occurring

Impact Score = 0 –1.0 based on an Impact Matrix such as shown in Exhibit VIII.

A P-I score can then be used to determine the level of response required. For examples, scores over 0.180 in the Exhibit IX matrix indicate a higher level of response required. With a threshold of .18, the P-I scores requiring the highest response are highlighted in orange. Moderate scores are highlighted in yellow.

EXHIBIT IX. Probability – Impact (Based on PMBOK Guide, 2000, 137)

	Impact Score				
Probability Score	*.05*	*.1*	*.2*	*.4*	*.8*
.9	.045	.090	.180	.360	.720
.7	.035	.070	.140	.280	.560
.5	.025	.050	.100	.200	.400
.3	.015	.030	.060	.120	.240
.1	.005	.010	.020	.040	.080

CASE I RISK ANALYSIS

CHEMICAL PLAN CONTROL SYSTEM UPGRADE PROJECT

As noted earlier, Case I was an actual project with no front end loading. Several actual problems occurred that presented additional costs and delays for the duration of the project. These are listed in Exhibit X. What if Front End Loading had been included? This table compares the predicted outcome had an FEL study been done prior to the design work. A complete and thorough FEL study that investigated potential problem areas would have captured these problems early in the project. Assuming that a good study would have discovered problems early, the estimated cost based on action at an earlier date is shown.

The actual cost of the additions was $125,000. This was the budget overrun for this project. A significant portion of the project profitability was lost due to these overruns. Had these problems been discovered earlier, the cost impact would have been only $27,000. The difference is largely due to the rework caused by problems found in late stages when such changes are more expensive.

Changes that occur during construction can be very expensive. Construction workers and materials may be idle as engineering is required to redesign around the change. Items that may have been installed may need to be removed and may be unusable. Additional travel and living expenses are also required. For Case I, the engineering change to modify cable design not only required the engineering design, it required travel to the site to investigate and supervise the changes. As mentioned earlier, the benefit of an FEL study may not eliminate the project change. However, the cost and schedule impact is much less if discovered earlier.

The impact on schedule delay is also significant. For Case I, there was a 61-day delay in the schedule due to project changes. There would have been only a 10 additional days in the schedule had an FEL study been done. The 10 days are due to the FEL site survey needed and would not have been viewed as a schedule day if included in the original plans. In this case, the additional cost and time of an FEL study would have been small relative to the unforeseen costs and delays.

EXHIBIT X

CASE I: CHEMICAL PLANT CONTROL SYSTEM UPGRADE	ACTUAL TIME OF EVENT AND IMPACT ON PROJECT WITH NO FEL			ANTICIPATED PROJECT OUTCOME HAD FEL BEEN IMPLEMENTED						
Risk Event during the Project	**Impact Discovery Time**	**Acutal Cost Impact ($)**	**Actual Sched. Impact (days)**	**Probability Impact based on FEL study**	**Highest Impact**	**Highest Impact Score**	**P-I Score**	**FEL Solution (if FEL had been implemented)**	**Cost Impact Using FEL ($)**	**Schedule Impact Using FEL (days)**
Minimal Space under Raised Floor for new cables.	Impact occurred during construction when problem discovered. Rework required	$27,000	10	0.9	Cost	0.4	0.36	Use a different cable design approach	$5,000	0
Configuration Code found to be poorly documented	Impact occurred during design when exiting code problems discovered. Rework required	$60,000	40	0.9	Sched.	0.8	0.72	Have client identify problem code areas early in the project	$10,000	
System Grounding different from drawings	Impact occurred during construction when discovered	$13,000	5	1	Cost	0.2	0.2	Mark-up existing drawings during FEL	$1,000	0
Existing Intrinsic Safety Barriers do not interface correctly with new control system	Impact Occurred during design review	$20,000	5	0.9	Cost	0.2	0.18	Utilize different Input Output Cards	$1,000	0
Length of cables were found to be too short to move some existing cabinets during cutover	Impact was found during cutover and required layout re-design while construction waited	$5,000	1	0.9	Cost	0.1	0.09	Incorporate layout design in FEL	$0	0
TOTAL		$125,000	61						$17,000	0
Additional time and Cost for FEL		$0	0						$10,000	10
TOTAL IMPACT		**$125,000**	**61**						**$27,000**	**10**

RISK ANALYSIS OF CASE II

COGENERATION PLANT CONTROL SYSTEM UPGRADE PROJECT

For Case I, there were no FEL processes included. The risk analysis looks at the impact FEL may have had on the project. The Case II project included FEL processes and was viewed as a highly successful project. The project was under budget, on schedule and received high praised from the client. What if FEL had not been included? Exhibit XI shows the actual problems discovered during the FEL phase of the project. It also shows the potential impact these problems would have presented if found during the later stages of the project.

The expected additional costs are estimated to be $124,000 with an estimated 15-day project delay. For this project, schedule delays were critical since the client imposed liquidated damages in the contract at $1000/day up to the limit of the contract amount.

There were two important items discovered during the FEL site survey. The wiring from field instruments to existing process control equipment was un-labeled and installed in a way that made removal difficult. This discovery changed the whole approach to the removal of existing equipment. At that point, it was only a design change and no additional costs were incurred. Had this discovery been made in later stages of the project, it would have imposed a significant cost and schedule delay to the project.

The second major discovery were problems found with a 1-mile data communication link between the cogeneration plant and a chemical plant that purchases steam. The communication link that was routed near steam lines was exposed to the heat and a high-maintenance problem. Not only was this problem averted, but also a more cost wireless approach was used to transmit data. The FEL study allowed a spread-spectrum evaluation to confirm that radio interference was not present and the line-of-sight between the two Yagi antennas would function within the losses allowed. Installing wireless communication without the study would have been risky. If wireless were found not to work, during construction, there was no suitable contingency plan to provide data communication.

A third problem was discovered but is shown with a much lower P-I score (.1). The impact of this problem was less severe and would not have been a significant impact on the project. There would have been additional time and wiring costs for extending the thermocouple wiring as noted. Even though some problems may have low scores they should not be overlooked or discounted. An FEL may generate a significant number of low P-I score events that present a significant project impact when taken as a whole.

This project highlights another advantage of the FEL study. When done early in the project, it allows the project team to take advantages of risk opportunities under SWOT analysis. FEL studies are known for averting problems early in the project and thereby reducing project costs and delays. The FEL study can also introduce alternative approaches using technologies and different design approaches that save the project time and schedule delays. In addition, Value-Engineering may be introduced to further improve the overall cost and budget risks.

EXHIBIT XI

CASEII: COGENERATION PLANT CONTROL SYSTEM UPGRADE	ANTICIPATED TIME OF EVENT AND IMPACT ON PROJECT IF NO FEL HAD BEEN INCLUDED			ACTUAL OUTCOME WITH FEL INCLUDED IN PROJECT						
Risk Event during the Project	**Anticipated Impact Discovery Time**	**Actual Cost Impact ($)**	**Actual Sched. Impact (days)**	**Probability Impact based on FEL study**	**Highest Impact**	**Highest Impact Score**	**P-I Score**	**FEL Solution (if FEL had been implemented)**	**Additional Cost Impact Using FEL ($)**	**Schedule Impact Using FEL (days)**
Disorganized and unlabeled Cables within Existing Cabinets	Likely found during construction resulting in delay and liquidated damages	$50,000	5	1	Cost	0.9	0.9	Reusing existing cabinets actually saved costs	-$20,000	0
More expensive Fiber Optic Communication along with startup problems due to heat from steam lines	More expensive approach had wireless not been investigated during FEL. Potential heat problems	$60,000	5	0.9	Sched.	0.9	0.81	Utilize cost effective wireless over 1 mile distance	$1,000	0
Extending Thermocouple wiring vs. using bus technologies	Additional wiring costs and time during installation	$5,000	5	1	Cost	0.1	0.1	Utilize bus techniques to extend Thermocouple Signals	$0	0
TOTAL		$115,000	15						-$19,000	0
Additional time and Cost for FEL		$0	0						$10,000	10
TOTAL IMPACT		**$115,000**	**15**						**-$9,000**	**10**

PROJECT RISK ANALYSIS COMPARISON

The Case I project did not include FEL and exceeded the project budget with schedule delays. Project risk analysis found that much of the impact was due to problems discovered late in the project. Had these problems been discovered early, many of the problems would have been averted.

The Case II project and Case I project were similar in scope and size. Case II included FEL and is considered a highly successful project. The Case II FEL study found several major problems during the early stages and many of these problems were averted. Case II project risk analyses estimates significant cost and schedule delays had these problems been discovered during construction or late phases of design.

It is interesting to note that the Case I project exceeded a $1 Million dollar budget by $125,000. Had an FEL not been completed for the Case II project, the budget over-run is estimated at $124,000 on a similar $1 Million budget. The actual and anticipated cost impact of both project are similar. Even though the projects were similar, the types of problems encountered were different and it is not possible to say a similar cost would be expected on another similar project. The cost is dependent on the types of problems uncovered during the course of the project.

Chapter 8

CONCLUSIONS

Front End Loading (FEL) is a well-established project process for improving the overall success of a project. Project success is measured by schedule, budget and scope. When applied to Control System Projects, the same success has been found.

The actual case studies presented in this paper support the current understanding and show that an FEL study contributes to the success of a project.

The FEL process is an important factor to the success of Control System Projects. Both clients and engineering firms will benefit by including this process in projects.

The FEL process can be improved by including formal risk analysis when identifying and evaluating the impact of potential problems. The tools and steps presented in this paper present a simple method to rank and identify risks as demonstrated with the two Control System Project Case Studies. Opportunities and threats can be determined as well as appropriate responses.

Chapter 9

RECOMMENDATIONS

Based on the literature and actual field experience with control system projects, the following is a list of recommendations when seeking to improve control system project success.

- In order to lay groundwork for a successful project, include Front End Loading during the early phase of the project. For existing plant upgrades, Front End loading should include a site survey with interaction with those who operate and maintain the existing control system

- The Site Survey Team should include the technical leads on the project. Uncovering technical problems is an important task during FEL studies. This requires experienced and technically knowledgeable individuals.

- The FEL study should include the 8 risk analysis steps identified in Chapter 7. Quantitative analysis may be used in situations where risk is high and accurate sample data can be used as input to a stochastic model.

- Include a formal risk analysis of all potential problems uncovered during the FEL Study. Each risk should be identified with the potential cost and schedule delay. A Probability-Impact analysis can be done to rank all risks identified.

- During the risk analysis and site survey, do not forget to include assessment of Opportunities as well as Threats. Alternative designs or creative solutions to problems utilizing newer technologies may significantly save project time and costs.

- A fast-track project may not appear to have time to include an FEL study. On the contrary, the FEL study will likely save the project time and expense by identifying serious problems in early stages of the project.

- The scope and deliverables identified for the FEL study need to be customized to the specific project needs. Every project is different with different problems and needs. The FEL study should remain flexible to adjust the overall project plan based on identified threats and opportunities.

Chapter 10

SUGGESTIONS FOR ADDITIONAL WORK

Front End Loading has been identified as a means to improve project performance. However, specific methodologies vary. Several articles have been written on benefits but methods vary between projects.

Much has been written on risk analysis and this is certainly an area that can be incorporated in FEL Studies as demonstrated in this paper.

More work can be done in applying risk analysis tools to control system projects with different scope and size. Specific areas of further study are below:

- This paper examines two similar case studies. The same analysis can be applied to projects that have larger scope and scale.

- Many control system projects are for new process plants. This paper focuses on upgrade projects for existing plants. The FEL process required for new projects is different since the site survey does not apply to a "grass roots plant". Risk analysis techniques still apply and benefits have been reported when FEL Studies are included. The use of risk analysis tools for new projects is an area for further study.

- Further work can be done as more experience and data is gathered. Quantitative analysis has restricted application with poor historical data to establish distribution types and parameters. Additional risk analysis tools may prove to be beneficial. Given accurate historical data quantitative risk analysis tools using Monte Carl simulation will assist in the estimation process and risk analysis. Some work has been done specific to construction cost estimating and simulation for projects (Hulette 2003) (Fente 1999). These tools can be used in FEL studies to evaluate project budgets schedules and contingencies. The development of both quantitative ad qualitative risk analysis tools specific to the FEL process is an area of further study.

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