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MAKING ZERO REWORK A REALITY:  
A COMPARISON OF ZERO ACCIDENT  
METHODOLOGY TO ZERO REWORK AND  
QUALITY MANAGEMENT

by

NORTH DAKOTA STATE UNIVERSITY

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GARY R. SMITH

TED JIRIK

Research Report 203-11

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A COMPARISON OF ZERO ACCIDENT METHODOLOGY  
TO ZERO REWORK AND QUALITY MANAGEMENT

by

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

Under the Guidance of  
CII Project Team 203  
Do It Right the First Time

CII Research Report 203-11  
March 2006

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## Executive Summary

While the construction industry has made great strides in improving its safety record over the last decade, the same cannot clearly be said regarding rework. Rework measures over the past decade have not shown any measurable improvement. Therefore, the Construction Industry Institute sponsored the “Do It Right the First Time” Research Team to investigate what can be learned from safety program implementation that might impact rework. The research identified and described the major components of a comprehensive process for management and elimination of quality-error related costs for construction sites. The focus of this project was on the implementation of error-reduction activities on the project execution level.

The research team looked at methods and techniques that have been effective in implementing safety management and in reducing accidents and lost workdays in construction. A survey that engaged respondents on safety management and quality or rework questions was developed. It found that management support and pre-project tasks for were consistent for both safety and quality activities. One difference occurs in the implementation level between planning and field execution. Most importantly, the research found that worker involvement is needed to resolve the continuing problem of rework. Specifically, the research team found that increasing training on quality issues, identifying quality rework problem areas, increasing full-time quality staff, and having field personnel analyze pre-task quality efforts all contribute to less rework.

## Table of Contents

| Section                                                    | Page |
|------------------------------------------------------------|------|
| <b>List of Figures</b> .....                               | v    |
| <b>List of Tables</b> .....                                | vi   |
| <b>Chapter 1 Introduction</b> .....                        | 1    |
| 1.1 Background.....                                        | 1    |
| 1.2 Value Added.....                                       | 2    |
| 1.3 Beneficiaries of the Research.....                     | 3    |
| 1.4 Purpose .....                                          | 3    |
| 1.5 Objective and Tasks.....                               | 4    |
| 1.6 Methodology.....                                       | 5    |
| 1.7 Limitations of the Research.....                       | 6    |
| <b>Chapter 2 Literature Review</b> .....                   | 7    |
| 2.1 Introduction.....                                      | 7    |
| 2.2 Safety Management .....                                | 7    |
| 2.3 Rework Reduction Management Systems .....              | 8    |
| 2.4 Other Rework Studies.....                              | 10   |
| 2.5 Possible Shift Needed.....                             | 11   |
| 2.6 Education and Training for Rework Reduction.....       | 11   |
| 2.7 Integrated Quality and Safety Management Systems ..... | 12   |
| 2.8 Literature Review Summary.....                         | 15   |
| <b>Chapter 3 Methodology</b> .....                         | 16   |
| 3.1 Introduction.....                                      | 16   |
| 3.2 Survey Development.....                                | 16   |
| 3.2.1 Demonstrated Management Commitment.....              | 16   |
| 3.2.2 Staffing for Safety.....                             | 17   |
| 3.2.3 Pre-project and Pre-task planning.....               | 17   |
| 3.2.4 Education.....                                       | 18   |
| 3.2.5 Worker Participation and Reward.....                 | 18   |
| 3.2.6 Subcontract Management.....                          | 19   |
| 3.2.7 Accident or Incident Investigations.....             | 19   |
| 3.2.8 Drug and Alcohol Testing.....                        | 19   |
| 3.2.9 Contract type.....                                   | 20   |
| 3.3 Survey Content.....                                    | 20   |
| 3.4 Survey Distribution.....                               | 22   |
| 3.5 Follow-up Data Collection.....                         | 23   |
| <b>Chapter 4 Analysis</b> .....                            | 24   |
| 4.1 Survey Demographics.....                               | 24   |
| 4.2 Data Classification .....                              | 25   |
| 4.3 Demonstrated Management Commitment.....                | 26   |
| 4.3.1 Management Accountability.....                       | 26   |
| 4.3.2 Standards Adoption.....                              | 27   |
| 4.3.3 Audits by Management.....                            | 27   |
| 4.3.4 Prequalification.....                                | 28   |
| 4.3.5 Reporting.....                                       | 28   |

## Table of Contents continued

| Section                                                     | Page      |
|-------------------------------------------------------------|-----------|
| 4.3.6 Project Goals Established.....                        | 29        |
| 4.4 Staffing.....                                           | 30        |
| 4.4.1 Full-time Staffing and Part-time Staffing Levels..... | 30        |
| 4.4.2 Functional Integration.....                           | 32        |
| 4.4.3 Qualifications.....                                   | 33        |
| 4.4.4 Staff Reporting Hierarchy.....                        | 34        |
| 4.5 Pre-project and Pre-task Planning.....                  | 35        |
| 4.5.1 Site Specific Planning.....                           | 35        |
| 4.5.2 Job Hazard Analysis.....                              | 36        |
| 4.5.3 Risk Management and Communication.....                | 36        |
| 4.5.4 Pre-Task Planning.....                                | 37        |
| 4.5.5 Constructability Review.....                          | 38        |
| 4.6 Education and Training.....                             | 38        |
| 4.6.1 Training Time.....                                    | 38        |
| 4.6.2 Budgets.....                                          | 39        |
| 4.6.3 Skills Based Training.....                            | 40        |
| 4.6.4 Tool-box Talks.....                                   | 41        |
| 4.6.5 Standard Orientations.....                            | 41        |
| 4.7 Worker Participation and Involvement.....               | 42        |
| 4.7.1 Stop Work.....                                        | 42        |
| 4.7.2 Behavior Based.....                                   | 43        |
| 4.7.3 Craft Level Input for Audits.....                     | 43        |
| 4.8 Evaluation, Recognition and Rewards.....                | 44        |
| 4.8.1 Contract Incentives.....                              | 44        |
| 4.8.2 Craft Incentives and Frequency.....                   | 45        |
| 4.8.3 Discipline Process.....                               | 46        |
| 4.9 Subcontract Management.....                             | 46        |
| 4.9.1 Subcontractor Planning.....                           | 46        |
| 4.9.2 Qualification.....                                    | 47        |
| 4.9.3 Subcontract Goals.....                                | 48        |
| 4.10 Investigations and Reporting .....                     | 48        |
| 4.10.1 Sanctions.....                                       | 48        |
| 4.10.2 Near Misses, Investigations and Reporting.....       | 49        |
| 4.11 Drug and Alcohol Testing.....                          | 52        |
| 4.12 Data Analysis.....                                     | 52        |
| 4.13 Rework Reduction vs. Safety Management System.....     | 57        |
| 4.14 Root Cause Analysis.....                               | 60        |
| 4.15 Contract type.....                                     | 64        |
| 4.16 Comprehensive Processes.....                           | 65        |
| 4.17 Summary of Data Analysis.....                          | 66        |
| <b>Chapter 5 Conclusions and Recommendations.....</b>       | <b>67</b> |
| 5.1 Conclusions.....                                        | 67        |
| 5.1.1 Demonstrated Management Commitment.....               | 67        |
| 5.1.2 Staffing Levels.....                                  | 67        |

## Table of Contents continued

| Section                                              | Page |
|------------------------------------------------------|------|
| 5.1.3 Safety Planning pre-project and pre-task ..... | 68   |
| 5.1.4 Education.....                                 | 68   |
| 5.1.5 Worker Participation and Reward .....          | 69   |
| 5.1.6 Subcontract Management.....                    | 70   |
| 5.1.7 Accident or Incident Investigations.....       | 70   |
| 5.1.8 Drug and Alcohol Testing.....                  | 71   |
| 5.2 Recommendations.....                             | 71   |
| <b>References</b> .....                              | 72   |
| <b>Appendix A Survey</b> .....                       | 74   |

## LIST OF FIGURES

| Figure                                                        | Page |
|---------------------------------------------------------------|------|
| 4.1 Safety and Quality Management Scores.....                 | 60   |
| 4.2 One Example from a ‘Top Five List’ .....                  | 61   |
| 4.3 Root Cause Plot Identifying Root Cause and Frequency..... | 62   |
| 4.4 Contract Type and Total Rework Percentage.....            | 64   |
| 4.5 Contract Type and Field Rework Percentage.....            | 64   |
| 4.6 Hypothetical Process to Reduce Field Rework.....          | 65   |

## LIST OF TABLES

| Table                                                              | Page |
|--------------------------------------------------------------------|------|
| 2.1 Primary Research Materials On Rework.....                      | 9    |
| 2.2 Literature Summary of Rework Rates.....                        | 11   |
| 2.3 Summary of the Literature by System Elements.....              | 14   |
| 3.1 Comparison.....                                                | 21   |
| 4.1 Project Breakdown .....                                        | 24   |
| 4.2 Project Breakdown by Project Conditions.....                   | 24   |
| 4.3 Number of Owner and Contractor Responses.....                  | 25   |
| 4.4 Data Analysis Presentation Format.....                         | 25   |
| 4.5 Management Accountability.....                                 | 26   |
| 4.6 Conducting Audits.....                                         | 27   |
| 4.7 Prequalification Comparison.....                               | 28   |
| 4.8 Management Reporting.....                                      | 29   |
| 4.9 Project Goal Setting.....                                      | 30   |
| 4.10 Full Time Personnel.....                                      | 31   |
| 4.11 Comparison of Staffing Levels.....                            | 32   |
| 4.12 Part-time Personnel.....                                      | 32   |
| 4.13 Functional Integration on Project.....                        | 33   |
| 4.14 Certifications or Qualifications of Full-time Personnel.....  | 33   |
| 4.15 Certifications or Qualifications for Part-time Personnel..... | 34   |
| 4.16 Management Reporting Hierarchy.....                           | 35   |
| 4.17 Planning.....                                                 | 36   |
| 4.18 Job Hazard or Quality Analysis.....                           | 36   |
| 4.19 Risk Management and Communication Plan.....                   | 37   |
| 4.20 Pre-task Planning.....                                        | 38   |
| 4.21 Constructability Reviews.....                                 | 38   |
| 4.22 Training Hours.....                                           | 39   |
| 4.23 Budgets for Training.....                                     | 40   |
| 4.24 Skills Based Testing.....                                     | 40   |
| 4.25 Tool-box Talks.....                                           | 41   |
| 4.26 Standard Orientations.....                                    | 42   |
| 4.27 Stop Work Authority.....                                      | 43   |
| 4.28 Behavior Based Programs.....                                  | 43   |
| 4.29 Auditing With Craft Level Input.....                          | 44   |
| 4.30 Contract Incentives or Rewards.....                           | 45   |
| 4.31 Craft Level Incentives.....                                   | 45   |
| 4.32 Incentive Frequency.....                                      | 46   |
| 4.33 Worker Discipline Process.....                                | 46   |
| 4.34 Subcontractor Planning.....                                   | 47   |
| 4.35 Subcontractor Qualification.....                              | 48   |
| 4.36 Subcontractor Safety Goals.....                               | 48   |
| 4.37 Subcontractor Sanctions or Incentives.....                    | 49   |
| 4.38 Near Miss Reporting.....                                      | 50   |
| 4.39 Reporting Mechanism.....                                      | 50   |

## LIST OF TABLES continued

| Table                                                                       | Page |
|-----------------------------------------------------------------------------|------|
| 4.40 Incident Investigations.....                                           | 51   |
| 4.41 “For Cause” Testing.....                                               | 52   |
| 4.42 Kappa Statistics for Selected Paired Questions.....                    | 54   |
| 4.43 Coefficients for Safety and Rework Reduction Survey Question Pairs.... | 56   |
| 4.44 Survey Paired Questions for System Comparison.....                     | 57   |
| 4.45 TRIR Comparison.....                                                   | 58   |
| 4.46 Score Comparison.....                                                  | 59   |
| 4.47 Pearson’s correlation coefficient for safety and quality scores.....   | 60   |
| 4.48 Rework Data Reported                                                   | 63   |

# Chapter 1

## Introduction

### 1.1 Background

Rework is generally accepted as a ‘cost of doing business.’ Rework cost is rationalized as an acceptable price to pay based on how fast a schedule is pushed or how poorly requirements were defined. However, in many instances rework impacts are more complex than simply an added cost to overall performance. Rework also can impact staffing requirements, administrative load, and operating facility activities. Previous CII research has documented the impact of rework on projects and developed a detailed methodology for tracking rework cost or the cost of quality. The methods developed to track the cost of quality have demonstrated a significant cost impact, but tend to follow traditional productivity measurements. They stop short of providing an effective method to identify opportunities for improvement or remediation of the causal factors. The result is in many aspects a “mistakes will happen” attitude and a cost correction is made in project budgets. Acceptance of the “mistakes will happen” attitude is akin to the attitudes and belief systems that supported the “accidents will happen” approach to safety 20 years ago. Extensive study and experimentation with improvement techniques in safety has produced dramatic progress toward reducing the overall impact of accidents; concurrently little has been done to reduce the occurrence of errors. Mistakes or errors, like accidents, are preventable.

Safety improvements have been brought about through corporate cultural and changes in safety system processes. The level of emphasis and accountability placed on all levels of corporate management and project participants has shifted with this increased

knowledge. No longer is safety simply a set of compliance, nor is it simply a senior management mantra, there is recognition in most companies that active management of safety plays a significant role in the process itself and active management results in significant cost savings in reduced total costs of injuries, workman's compensation costs and other insurance costs. While quality savings may not result in insurance savings, the direct and indirect cost impacts coupled with fewer schedule disruptions from errors in the process will yield significant savings also. Are there fundamental concepts from safety management that can be carried over to the quality arena to reduce errors? This question is the focus of this project and report.

The literature has a wealth of information on the successful management practices, tools, training and planning used in safety programs. Internationally, several researchers have looked at implementing combined quality and safety systems to take advantage of the synergism between the management systems. There may be ideas to implement from these efforts. Designers, vendors, the owners and contractors all have some role and function in the improvement of safety and quality, including reduction of rework.

## **1.2 Value Added**

Given that safety improvement research has been conducted for more than a decade, this research forms the foundation for studies geared toward the reduction of errors through proactive processes and practices. The potential for savings to the individual companies and the industry generally is demonstrated by previous CII research on the cost of quality (CII, May 1989). Based on detailed analysis of 9 projects, the study

showed 12% of the Total Installed Cost (TIC) was rework. More recent studies show a lower total cost but still in a significant range for justifying improvements. Like safety, the indirect costs could be much greater and the study conservatively estimated 20%-30% of project-installed cost. However, no efforts have been made to secure data on indirect costs associated with rework. In addition to cost savings, resulting claims and litigation created from project changes and revisions should also be reduced. Thus, reducing the cost of errors in the capital project delivery process could be next major element of savings available to lower capital project costs and improve industrial competitiveness.

### **1.3 Beneficiaries of the Research**

The broad scope of the research would be applicable to all participants in every phase of the project. Owners, designers, contractors, and vendors would benefit from error reduction. Owners would ultimately benefit from reduced project costs. Designers would have less rework and evaluation, once the error reduction process includes design. Contractors would benefit clearly from reduced interruptions and added costs of their own mistakes not included in change orders. Vendors would also benefit from not having reshipping, re-fabrication costs or restocking charges.

### **1.4 Purpose**

The purpose of this research is to identify and describe methods and techniques to reduce field error problems. The primary components of a comprehensive management process for management and elimination of quality error related costs for construction sites will also be defined.

## 1.5 Objective and Tasks

The objective of the research is to identify and evaluate safety program components that may be convertible to quality processes that have a likelihood of an acceptable outcome on the first try. To accomplish the objective the following tasks were identified.

**Task 1.** Investigate the literature available on safety and quality inter-relationships. A wide variety of information is published on safety management methods and procedures and on quality management methods and procedures. However, the field of literature focused on one benefiting the other is limited. Internationally the literature also contains references to combined safety and quality management processes that should be examined for appropriate content.

**Task 2.** Identify processes that have been implemented with the goal or purpose to reduce error in field level construction. Construction zero defect programs, when adapted from industrial manufacturing environments did not transfer successfully in many cases to the construction environment due to the traditional environmental barriers. However, there may be important lessons learned from these early failures. The literature will be examined for records of these efforts.

**Task 3.** Prepare a survey of projects on safety and quality processes. The dual nature of the survey will enable comparisons of safety and quality (rework reduction) on a variety of projects. Of particular interest are the tools used to reduce field level research. To

reduce the variability in the data received, the survey will be conducted on projects that exhibit good safety practices. Analyze the survey data for commonalities and relationships between safety and quality.

**Task 4.** Formulate a comprehensive “zero-rework” management process based on the results of comparing the findings of the literature and data collected from active project systems in safety and, potentially, from active defect management processes.

## **1.6 Methodology**

The methodology used in the study is summarized as follows:

- Conduct a literature survey and examine materials specific to quality and safety related interfaces.
- Develop a survey for distribution to CII member companies for project responses. Projects to be included in the study were defined as those having effective safety programs in place.
- Collect data from volunteer projects using the survey instrument. Following the survey, preliminary analysis of the rework and quality management questions was performed to identify target projects for follow-up interviews.
- Data from the survey were analyzed using standard statistical tests and methods.
- Survey information was categorized for comparative purposes.
- Specific practices were examined relative to the safety data and rework data provided in the survey.

- The literature and lessons learned during the survey will be used to build the proposed process for field rework reduction.

### **1.7 Limitations of the Research**

The major limiting factors to the consideration of results in the study are as follow:

1. There was no comparative study to see if the results of this effort were similar to those obtained in other studies on safety and rework. Each subject has been independently studied to some extent but not studied as a combined subject matter with respect to commonality features.
2. The extensive survey was only distributed to volunteer projects. The request was made for projects that currently followed very effective safety practices. The purpose of the request was to reduce the response variability on the safety side. The general hypothesis was that where synergy existed between safety and quality it would more effectively identified from data that were as consistent as possible in one of the two management processes.
3. The study does not attempt to define indirect costs of rework. This remains an independent subject for later examination.

## Chapter 2

### Literature Review

#### 2.1 Introduction

The literature review focused on those documents that reported successful methods or systems for lowering occupational injuries or reducing rework. As a result general safety and general quality management systems were also researched for assistance with rework management solutions as general background information. A key activity of the literature review was to identify any existing materials that compared safety management and rework or quality systems.

#### 2.2 Safety Management

Finding effective safety management practices that decreased injury rates was an important focus for the literature review. There is a broad and detailed body of literature in safety and much of it focuses on prevention and accident causation factors. The most relevant research to this project's focus was from work performed for the Construction Industry Institute in the *Safety Plus: Making Zero Accidents a Reality* (February 2003). The findings are quickly summarized as follows:

“This study identifies the current best practices in the construction industry that make a difference in safety performance and that move the industry toward the goal of zero accidents. The Making Zero Accidents A Reality Project Team identified the following nine key topic areas that contribute to improved safety performance:

1. Demonstrated management commitment
2. Staffing for safety
3. Planning: pre-project and pre-task
4. Safety education: orientation and specialized training
5. Worker involvement

6. Evaluation and recognition/reward
7. Subcontract management
8. Accident/incident investigations
9. Drug and alcohol testing”

The research team continues by saying that the listing is not prioritized and only represents a listing of the topics and they should be considered as a group as being effective not individually. Additional detail breakdown on each of the nine elements was provided in the paper including a tenth element on contract type that was not included in the key elements. The full text of the literature survey this work is based on can be reviewed in *Making Zero Injuries a Reality, CII 160-11(Hinzie, March 2002)*. The 160-11 research report and 160-1 summary report represent the combined research and best of class understanding of effective safety programs at the time this project was initiated. Other safety materials were reviewed for this project, but none had the consistency of message and complete systems approach as presented in CII 160-11. As such it represented a point of beginning to examine the literature on rework and quality issues as they relate to safety programs.

### **2.3 Rework Reduction Management Systems**

Rework also has a solid foundation of research sponsored by CII. However, it lacks the long term consistency of effort as represented by safety research. Of most importance at the start of rework research were efforts to define and quantify the amount of rework on projects. The principal reports in this series of reports are presented below in Table 2.1

Table 2.1 Primary Research Materials On Rework

| <b>Publisher</b>      | <b>Publication Details</b>                                                                               |
|-----------------------|----------------------------------------------------------------------------------------------------------|
| CII                   | Costs of Quality Deviations in Design and Construction, Publication 10-1, January 1989                   |
| CII                   | Measuring the Cost of Quality in Design and Construction, Publication 10-2, May 1989                     |
| CII                   | Quality Performance Measurements Of The EPC Process: Current Practices, Source Document 79, October 1992 |
| CII                   | Measuring Quality Performance on EPC Projects, Summary Report 36-1, November 1994                        |
| CII                   | The Blueprint: A Process for Measuring Project Quality, Summary Report 36-2, December 1994               |
| CII                   | The Field Rework Index: Early Warning for Field Rework and Cost Growth, Summary Report 153-1, May 2001   |
| University of Alberta | Measuring and Classifying Construction Field Rework: A Pilot Study, May 2003                             |

Ledbetter (March, 1994) addressed rework quality performance using materials that were developed in CII Research Summary 36-2. The seven root causes for deviations or events needing rework are as follows:

1. Constructor error or omission made by constructor on product/process
2. Constructor change made by constructor on product/process
3. Owner change authorized by owner
4. Designer change made by designer in design of product/process
5. Vendor change made by vendor to purchased product
6. Designer error or omission made by designer or product/process
7. Vendor error or omission made by vendor furnishing product

This research focus is on constructor change and constructor error causes of rework.

The difficult issue specifically for a quality management system addressing rework on construction site projects is to implement the system effectively at the field level where defects occur. The predominate subject of the past research and reports in the literature have to do with monitoring the cost of rework and assignment of responsibility (classification) and not with methods or practices that effectively impact rework reduction.

## 2.4 Other Rework Studies

Love and J. Smith (1999) used a case study approach to develop a series of benchmark metrics for the cost and causes of rework. It is imperative that benchmark metrics are found and be measured to identify areas where rework can be decreased for cost savings to be realized. The implementation of a generic framework for benchmarking rework in project phases was also proposed by Love and J. Smith (1999). A quality measure similar to the common employer modification rate (EMR) used in safety measures could be designated to measure the levels of rework per construction company. A CII study proposed Equation 1 as a metric to measure the level of rework present (CII, May 2001):

$$\text{Cost of Rework} = (\text{Total Direct Cost Field Rework}) / (\text{Actual Construction Phase Cost}) \quad (1)$$

Indirect costs concerning rework must be included in the quality goals, otherwise only the tip of the ice berg of rework costs is counted. However, like safety, the actual cost of indirect rework costs has not been measured and cannot be included in the cost of rework formulation. Table 2.2 summarizes the rework rates published in several CII publications.

Table 2.2 Literature Summary of Rework Rates

| References                                                      | Field Rework Percentage                                                               | Project Data                                     |
|-----------------------------------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------|
| Research Summary 10-1 (1989)                                    | 12%<br>(9.5% design, and<br>2.5% construction)                                        | 9 industrial projects                            |
| Benchmarking & Metrics Data Report (1997)                       | 3.4%                                                                                  | 19 industrial projects                           |
| Investigation of Field Rework in Industrial Construction (2001) | 4.4%<br>(0%-25% Range)                                                                | 109 industrial projects                          |
| Impacts of Delivery Systems (2002)                              | 2.8% DB Owners<br>5.0% DB Contractors<br><br>2.50% DBB Owners<br>3.0% DBB Contractors | CII Benchmarking Database 326 projects all types |

## 2.5 Possible Shift Needed

The occurrence of rework on many projects is assumed to be a normal cost of work or a consistent pattern that cannot be changed. The related attitude would be “mistakes happen.” This thought process is somewhat analogous to the attitudes about construction safety 20 years ago, when it was assumed a certain number of employees would be injured or killed on a project. When prevention became the focus, the occurrence of injuries began to decrease. Fewer injuries facilitated decreases in insurance and worker compensation premiums. Similar benefits are apparent for decreasing rework on construction projects.

## 2.6 Education and Training for Rework Reduction

In the construction industry, to ensure rework reduction, Koehn (Sept 2003) proposed to include the following elements in education orientation and training:

- 1) Define rework reduction so all will understand it in terms of their work,
- 2) Involve contractors and employees in decision making,
- 3) Describe consequences of rework,
- 4) Development goals and feedback for rework reduction issues,
- 5) Provide self monitoring,
- 6) Recognize good performance.

Training and education are an established element in management systems for safety but it is not reported as being an established element with respect to rework and quality management.

Management must be committed to rework reductions to be realized, otherwise unplanned disturbances will interfere with the project schedule, Love (Aug 2002). If management is committed to rework reduction by putting time and resources into an effective system, then rework direct and indirect will decrease. The management system to be effective must involve the buy-in of management and employees who share in the benefits of the successful system.

## **2.7 Integrated Quality and Safety Management Systems**

Several authors have set out to show that effective safety and rework reduction management systems have many similarities. Many techniques may be interchangeable and be effective in both arenas. Krause (1994) stated that quality and behavioral safety have an analogous foundation in scientific methodology with eight techniques:

- Have constancy of purpose
- Implement a process, not a program
- Do it right the first time
- Don't blame the employee
- Specific standards in operational terms

- Use measurement of upstream factors to assess performance
- Improve the process, not the downstream results
- Use statistical techniques to distinguish common cause variation from special cause variation.

Krause presented a hypothesis that “behavior-based safety management and continuous quality improvement are closely related, perhaps so closely that they are essentially two sides of the same coin.”

Essentially Krause proposed applying quality management principles to the improvement of quality. This was also supported by Smith (1998) where a comparison between total quality management and safety was completed based on TQM practices at that time.

The safety and quality management system literature is summarized in Table 2.4. The CII and Gilkey approach were more developed for state workmen compensation and OSHA regulations require recording of safety metrics. These agencies have implemented consequences for high injuries rates. The quality systems research literature has some equivalent elements as seen in Table 2.2, but no universally required quality metrics assist. Also, the quality management systems are not a requirement by law.

Smith (1995) stated that “few implementation strategies exist that have any consistency. Unless a firm has implemented some sort of continuous improvement culture, the chances for innovation development or implementation to occur at the project level are small.” For these systems to be effective, the Plan-Do-Check-Act cycle (Shewhart, 1939) must be functioning on a field level.

The literature review has demonstrated that a significant body of knowledge exists on safety management. Rework research has focused on classification and measuring the amount of rework while not considering other impact issues. Table 2.4 summarizes the literature research findings by the 9 point framework defined in CII Research Summary 160-1(Feb 2003). Each system element contains the key references found in the literature review. Not surprisingly quality systems authors have reviewed many similar subjects, but none have consolidated the review in a consistent format.

Table 2.3 Summary of the Literature by System Elements

| <b>System Elements</b>                                        | <b>Safety Systems</b>                                       | <b>Quality Systems</b>                                                                   |
|---------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------------------------------------|
| <b><i>Demonstrated Management Commitment</i></b>              | Gilkey, 1998<br>CII, Feb 2003                               | Walton, 1989<br>Love (Aug, 2002)                                                         |
| <b><i>Staffing</i></b>                                        | CII, Feb 2003                                               | None found                                                                               |
| <b><i>Pre-project and pre-task planning</i></b>               | CII, May 1993<br>CII, May 2001<br>CII, Feb 2003             | Besterfield 1998                                                                         |
| <b><i>Education: orientation and specialized training</i></b> | CII, May 1993<br>Gilkey, 1998<br>CII, Feb 2003              | Walton, 1989<br>Koehn, Sept 2003                                                         |
| <b><i>Worker Participation and Involvement</i></b>            | Gilkey, 1998<br>CII, Feb 2003                               | Li, July 2003                                                                            |
| <b><i>Evaluation and recognition/reward</i></b>               | Gilkey, 1998<br>CII, May 2001<br>CII, Feb 2003              | Walton, 1989<br>Besterfield, 1998<br>CII, May 2001<br>Alarcon , 2003<br>Koehn, Sept 2003 |
| <b><i>Subcontract management</i></b>                          | CII, Oct 1988 SD 38<br>CII, Oct 1988 SD 39<br>CII, Feb 2003 | Koehn, Sept 2003                                                                         |
| <b><i>Investigations</i></b>                                  | CII, May 1993<br>Gilkey, 1998<br>CII, Feb 2003              | Besterfield ,1998                                                                        |
| <b><i>Drug and alcohol testing</i></b>                        | CII, May 1993<br>CII, Feb 2003                              | None found                                                                               |

The consistency of the CII 160-1 review of literature and following research cannot be underestimated. As the most comprehensive safety report it forms the basis for considering an approach to researching the elements of safety programs that would most likely impact rework or quality issues on a construction site.

## **2.8 Literature Review Summary**

The literature review clearly highlights a lack of comparative studies for this project to start from or compare findings. While several papers were identified that specifically addressed common areas or similarities between safety and rework (quality) management, there was little, if any, data collected from projects to support the value proposition. The literature search provided a mechanism to prepare the basic survey methodology using the Making Zero Injuries a Reality, CII 160-11(Hinzie, March 2002) findings.

## **Chapter 3**

### **Methodology**

#### **3.1 Introduction**

The proposed data collection process for this project was initially a case study based research approach where specific information from projects would document the interaction and relationships between safety and quality management. Early in the research team meetings it was evident that the team was more comfortable with a survey based approach. The drive was to identify as much of the commonalities as possible. Their second concern was that a case study approach might not give the broad coverage needed to evaluate the potential for quality improvements from a limited number of projects. Thus, the scope of the project was rewritten within the team to address the execution of a survey instrument.

#### **3.2 Survey Development**

In the process of examining the literature a principal report was identified that captured the success factors for implementation of effective safety programs. Key points were taken from Safety Plus: Making Zero Accidents A Reality (Research Summary 160-1 February 2003) as a baseline for a ‘cross walk’ with reducing field rework and rework generally.

##### **3.2.1 Demonstrated Management Commitment**

Management commitment in safety was reflected through top managers conducting safety inspections, participation in training and accident investigations. Safer

projects were those in which company presidents were involved in all accident investigations. This research team was interested in determining who and how often top management participated in quality inspections and investigations of quality defects causing rework. Is upper management commitment in place for rework and quality management?

### **3.2.2 Staffing for Safety**

The study on safety revealed that almost all projects in their data had a full-time safety representative on site. Full time safety management personnel on projects were involved in regular project management meetings. Safety was integral with cost, schedule and quality reporting. The key questions on number of personnel dedicated full and part time to quality management activities is a clear point of comparison. The inclusion of quality personnel at project management meetings would also be a reflection of management commitment to the quality function on the project. Safety personnel are commonly required to have some form of qualification (certification) to serve in their role. It is assumed that inspection personnel in quality acceptance should have some form of certification to perform their project function. The last area included in the questionnaire involved who the senior safety and quality personnel reported to on-site. Is there evidence on projects that appropriate staffing levels are provided for managing rework and quality?

### **3.2.3 Pre-project and Pre-task planning**

In the safety research that formed the basis for the survey document, the use of job hazard analysis and constructability reviews were common elements. Site-specific

quality plans were not created for all projects, but site-specific safety plans were found on projects with the better safety records. A similar battery of questions for site-specific pre-task quality planning, job quality analysis and constructability reviews were included in the survey. These elements are key to describing what project level personnel are responsible for in the quality management planning for the project. Is there evidence of pre-project and pre-task planning targeting rework reduction?

### **3.2.4 Education**

Worker safety orientation was found to be common among the companies with the better safety records. Injury rates were higher on projects without worker orientation training. Safety training was reported to average 5.3 hours per month in the 160-1 report. Supporting this training was safety training as a project budget line-item on two thirds of the companies. Weekly tool box meetings were a key component of safety training. Rework reduction would likely benefit from worker orientation to quality processes on the project and specialized training when appropriate. The requirement of a line-item budget for quality training was included in the survey for comparison purposes. Is there formal training directed toward reducing rework on projects?

### **3.2.5 Worker Participation and Reward**

Half of the RS 160-1 respondents indicated they had a formal behavior-based safety program in place. Reinforcement of behavior was often supported with safety incentives. The frequency of incentive was also evaluated. The more frequent the recognition, the better the safety performance. Assuming that a behavior based quality