



AN INVESTIGATION OF FIELD REWORK IN INDUSTRIAL CONSTRUCTION

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The University of Texas at Austin

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Causes and Effects of Field Rework Research Team
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EXECUTIVE SUMMARY

“Activities in the field that have to be done more than once in the field, or activities that remove work previously installed as part of the project.” That’s how CII’s Causes and Effects of Field Rework Research Team defined field rework. As such, it is one of the most inefficient activities taking place on a construction site. Someone has to pay to install, remove, and reinstall.

In addition to the obvious cost impact of rework, there is general agreement that high rework increases the difficulty of achieving schedule targets. High levels of rework are likely to result in demotivated craftspersons, further reducing productivity and increasing costs. Quality of the end product may be affected.

The Construction Industry Institute (CII) formed the Causes and Effects of Field Rework Research Team in February 1998 and contracted with Oregon State University to research field rework in the industrial sector of the North American construction industry. The research objectives included investigating field rework measurement, determining major causes of rework, assessing the cost and schedule impact of rework, identifying practices to minimize rework, and developing a tool to provide early warning of high field rework during construction.

Four major data gathering activities were undertaken to accomplish research objectives. After an initial literature review, the research team surveyed CII membership to determine field rework attitudes and practices. A one-day focus group of construction industry managers with extensive experience measuring and managing field rework followed this effort. Site visits with in-depth interviews were made to six companies identified as leaders in managing field rework. A database containing measurements of field rework, independent variables identified as

potential predictors of rework, and parametric project data from completed projects was compiled and analyzed. In the end, the database consisted of 144 usable industrial projects.

The most tangible end product of the research is the development of the Field Rework Index (FRI). This is a simple tool intended for use by the project team one or more times during preconstruction phases of the project. It is used to provide early warning of field rework. The tool consists of 14 questions and a warning chart. The FRI can be computed, and its significance assessed in less than five minutes. Serendipitously, the research team discovered that the FRI also provides early warning of impending cost growth. Projects in the research database with FRI scores below 30 not only experienced low or very low rework, but also experienced negative cost growth.

Projects experiencing high levels of field rework can generally trace the causes back to engineering design, scope definition and pre-project planning, and even the alignment within the organization of the Owner for the project. Attempts to minimize field rework must start early in the project life.

Some companies track field rework through the use of CII's QPMS, introduced in 1989. Others incorporate rework management in their change management systems. Companies that do not track rework may find the flowchart developed by the research team useful for adapting existing change management procedures to include field rework.

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1.0 INTRODUCTION

The CII Field Rework Research Team was formed in February 1998 to study the impact on projects of rework occurring during field construction activities. The research team defined field rework as, “activities in the field that have to be done more than once in the field or activities which remove work previously installed as part of the project,” and proceeded to develop purpose, scope, and objectives for a research project (see below). CII contracted with Oregon State University to execute the research project. This report documents the research process and presents a summary of the findings.

1.1 Purpose, Scope, and Objectives

The following purpose, scope, and objectives were developed for the research project by the research team.

1.1.1 Purpose. To provide a vehicle to qualify, quantify, and predict rework. The data will be analyzed to determine the most prevalent causes, and methods to minimize or eliminate these causes will be investigated.

1.1.2 Scope. Conduct project case studies and collect data on best practices for measurement, reporting, and feedback mechanisms to identify source of, and impact of, rework. Research will focus on the heavy industrial sector of the North American construction industry. Focus will be on the cause of the most costly rework and those causes that appear to be most amenable to correction.

1.1.3 Objectives. Project objectives were as follows:

1. Determine the most efficient manner to uniformly and routinely categorize and record factors causing field rework.
2. Determine major causes of rework and their impact on cost and schedule.
3. Identify practices that most effectively minimize field rework.
4. Develop a tool that CII members can use to assist in identifying more frequent/costly causes of rework and take most cost-effective corrective measures.

1.2 Hypotheses

The two hypotheses developed for the field rework issue are as follows:

1. Field rework can be measured and the causes determined accurately and consistently across the industry.
2. An analysis of key project parameters initiated prior to construction allows prediction of cost and schedule impacts of field rework.

1.3 Expected Products of Research

Two products were expected to result from the research. They are described below:

1. Rework Measurement System. A CII implementation resource would be developed that details the who, what, when, where, and how of implementing and using a field rework measurement system.
2. Field Rework Index (FRI). This product envisioned a predictive tool used prior to the start of construction. The FRI would use a scoring sheet similar to the CII PDRI. The scoring sheet would be used to assess the level of field rework likely to occur.

High predictions of rework would lead project management to mobilize resources to mitigate damage already done and minimize field rework.

The initial efforts of the research team made it clear that lack of a rework measurement system is not a serious problem for the construction industry. A number of companies utilize CII's Quality Performance Measurement System (QPMS) to track their field rework. Several other companies use some adaptation of QPMS. One company's long-term experience with QPMS is documented in Chapter 6 of this report. Other companies have very good internal proprietary tracking systems for field rework.

Product one, above, quickly became a relatively minor part of the research effort. For those who don't already have a system, or don't want to use QPMS, a flow chart is presented in Chapter Six to provide a framework for adapting existing change management systems to the tracking of field rework.

The development of the FRI became the driving force for the research team. Chapters Four and Five discuss its development. The end result is presented in Chapter Five.

1.4 Organization

Chapter Two provides a brief summary of data collection activities. Chapters Three through Six are devoted to each of the four major data collection activities. For each activity, procedures used and data obtained are presented and discussed, and analyses are discussed. The discussion in Chapter Five of the analysis of the research database also presents the FRI tool developed as a result of that analysis. Chapter Six discusses rework tracking methods of several companies studied, including one company's extensive experience with QPMS. Chapter Six also

presents a flow chart for use of existing change management systems in measuring field rework.

Chapter Seven summarizes overall conclusions and recommendations drawn from the research.

2.0 METHODOLOGY

An initial literature review was helpful in developing the proposal for the research, but did not provide critical information for the remainder of the research effort. To develop the research products presented above, the research team developed a plan to collect data through four major activities.

- An industry survey.
- A focus group of industry experts.
- Assembly of a database of measured field rework and related project variables for completed projects.
- Site visits to six best practices companies.

An industry survey was conducted to determine current attitudes toward field rework and its measurement. The procedures used and results obtained from this data collection effort are discussed in Chapter Three.

The industry survey was followed by a focus group of industry managers with serious interest in and experience with field rework. The objective was to determine project factors that have strong influence on the level of field rework experienced during construction. This effort is discussed in Chapter Four.

A database of information from completed projects was compiled and analyzed to test the validity of the factors identified by the focus group and refined by research team discussions. This effort is discussed in Chapter Five.

Site visits with in-depth interviews were conducted with six construction industry companies determined to be leaders in measuring and managing field rework. Methodology and findings are presented in Chapter Six.

3.0 INDUSTRY SURVEY

In 1998, CII member companies were surveyed on their attitudes and practices regarding field rework. The objective of the survey was to learn about current industry practices with regard to measuring, predicting, and preventing field rework. The survey was distributed to 86 companies and a total of 85 individuals responded from 48 different companies. Appendix A contains the survey questionnaire. The results of the survey are presented in this section and provide insight into how companies have set up and utilized their field rework systems.

The responses came from various sectors of the construction industry. Figure 3.1 provides the breakdown of industry sectors for the survey's respondents. The category of "Process" includes petrochemical, chemical, food and paper products. The category of "Manufacturing" includes steel, automotive, and consumer products.

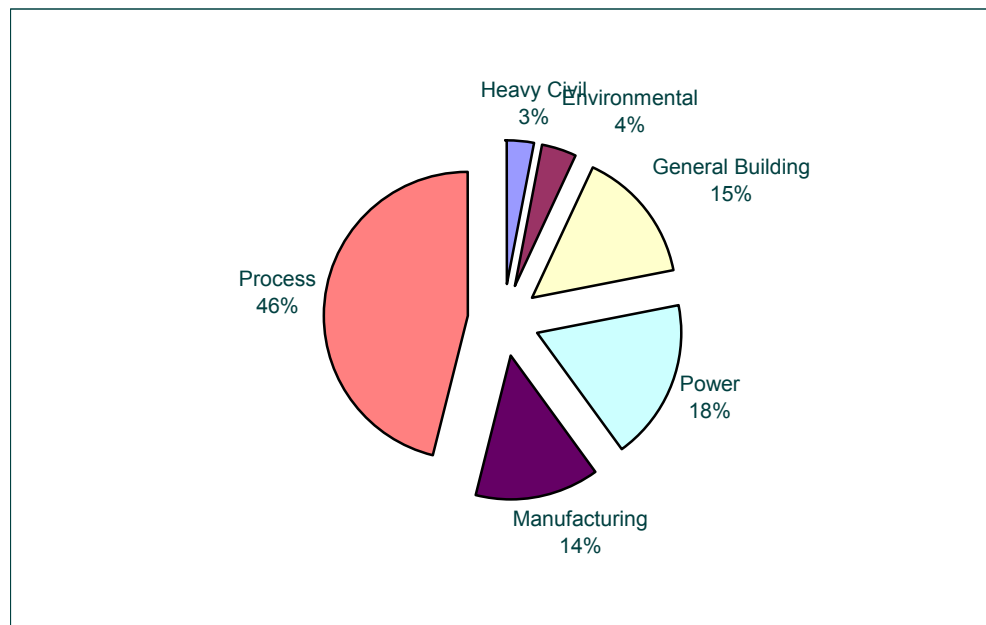


Figure 3.1. Industry Sector Breakdown for Survey Respondents

3.1 Tracking Rework and Rework Goals

A focus of the CII Field Rework research was minimizing field rework. In trying to minimize rework, it is essential to have a way of tracking rework and setting goals. It is difficult to improve rework if there is no understanding of the current level of rework. The information gathered can direct improvement efforts and allow for intelligent goal setting. To understand the current practices of companies on this topic, two important questions were asked. The topics were tracking rework and setting rework goals. The questions and responses are summarized in Tables 3.1 and 3.2.

Table 3.1. “Which statement most accurately summarizes the degree to which your company tracks field rework?”

Statement on Tracking Rework	Response from Survey
We never track the level of, cost of, or schedule impact of field rework	13%
Sometimes we track field rework, sometimes we don’t	39%
We always track field rework	48%

Table 3.2. “Which statement most accurately reflects your company’s attitude toward field rework?”

Attitude Toward Field Rework	Response from Survey
A target of zero field rework should be set for all projects.	44%
There is an optimal zero or non-zero level of field rework that should be targeted, based on project characteristics.	46%
Field rework happens. It’s simply not worthwhile to track it.	5%

The survey found 87 percent (Table 3.1) of respondents either “always” or “sometimes” tracked rework. This indicates that the vast majority of the respondents have some type of rework measurement system. While most of the respondents have tracked rework, the method of tracking rework is not the same for all companies. The disparities in methods of tracking rework will be evident in some of the survey results that will be presented later in this section.

It would seem likely that a larger percentage of CII companies would track field rework when compared to the overall construction industry. Factors that would increase the likelihood of CII companies tracking rework would be project types, contract requirements, resources available and more focus on improving operations.

The survey found 90 percent (Table 3.2) of respondents favored setting a target for field rework either at a “zero” level of rework or an “optimal non-zero” level of rework. Setting targets demonstrates a desire to control and reduce rework. To know if rework targets are being met, companies have to track rework and compare it against the target.

The measurement of rework allows a company to see if they are meeting their rework targets. If the rework is found to be unacceptably high, the companies can use the information to initiate activities to reduce rework on future projects. Providing direction for future improvement is one of the benefits of a measurement system.

Overall, these two survey questions show that most respondents have experience in measuring rework and believe in setting a target for rework. For those companies, this research will provide a valuable resource in improving their current systems. It will also be valuable to companies that currently do not include these practices, but are striving to find ways to reduce rework.

As shown in Figure 3.1, the process industry had the largest share of responses to the survey. There were some differences in the way the companies in the process industry answered the questions compared to the other industries. It should be noted that many companies had projects in multiple industries. In the following discussion, companies that had the largest percentage of projects in the process industry will be put into the process group for discussion.

In regards to tracking rework and setting goals, the results for the process industry versus the other industries are presented in Tables 3.3 and 3.4.

Table 3.3. “Which statement most accurately summarizes the degree to which your company tracks field rework?”

Statement on Tracking Rework	Process Industry	Other Industries
We never track the level of, cost of, or schedule impact of field rework	5%	19%
Sometimes we track field rework, sometimes we don't	36%	40%
We always track field rework	59%	36%

Table 3.4. “Which statement most accurately reflects your company's attitude toward field rework?”

Attitude Toward Field Rework	Process Industry	Other Industries
A target of zero field rework should be set for all projects.	27%	60%
There is an optimal zero or non-zero level of field rework that should be targeted, based on project characteristics.	61%	29%
Field rework happens. It's simply not worthwhile to track it.	5%	10%

The process industry is more likely to track rework compared to other industries. The survey found 95 percent of the process group either sometimes or always tracks rework, compared to 76 percent of other industries. In addition, there was a significant difference in how the groups set rework targets. The process industry was more likely to set rework targets based on project characteristics, while other industries were more likely to set a target of zero for all projects.

Perhaps, the process industry tracks rework more often because they experience higher rework levels. This statement is supported by the results shown in Table 3.4, where the process industry had only 27 percent targeting zero field rework on all projects versus 60 percent in other industries.

Based on the assumption that there are potentially higher rework levels in the process industry, there's a greater opportunity to reduce costs by reducing rework in that group. Therefore, the products of the CII "Field Rework" research may be incorporated into use quicker in the process industry.

3.2 QPMS

CII has developed a tool for tracking the cost of quality including rework (Construction Industry Institute, 1990). This tool is called the Quality Performance Management System (QPMS). To date, QPMS is the most comprehensive system developed by CII to track rework. Table 3.5 displays the survey results for a question concerning QPMS.

Table 3.5. “CII has developed a quality performance management system (QPMS) for measuring the cost of quality, which among other costs includes the cost of rework. What is your level of familiarity with QPMS?”

QPMS	Response from Survey
Never heard of it	47%
We have not tried it	32%
We have tried it, but discontinued its use	2%
We have borrowed and selected portions of the QPMS system	15%
We use QPMS almost exactly as presented in CII Research Summary 10.3	5%

The survey found 79 percent (Table 3.5) had never heard of or tried the QPMS. This could indicate that there is another measurement system that companies use. Or, it could indicate that there are many different measurement systems in use, with no single system being used by the majority of companies.

Companies establishing a system to measure rework or trying to improve their current system should examine QPMS for possible benefits. Section 4 of this report outlines Company X’s use of QPMS. Company X has reduced rework from 10.1 percent in 1988 to 3.6 percent in 1998 with the use of QPMS (Company X, 1998). The QPMS would provide a consistent method of tracking rework across companies. As discussed previously, it is difficult to direct rework improvement efforts without a clear understanding of the current level of rework. QPMS is a system that can provide the necessary data to direct quality improvement efforts.

An indication of the potential benefits of QPMS is the low number of companies that discontinued its use. From the survey, a total of 17 companies either tried or use all or a portion of the QPMS system. Out of these 17 companies, only two of the companies discontinued it.

The majority of companies that use QPMS must experience benefits from the system or a larger number would discontinue its use.

How did the 15 companies that use QPMS answer the questions on tracking rework and setting goals? Tables 3.6 and 3.7 summarize the results for those companies.

Table 3.6. “Which statement most accurately summarizes the degree to which your company tracks field rework?”

Statement on Tracking Rework	Response from Survey
We never track the level of, cost of, or schedule impact of field rework	0%
Sometimes we track field rework, sometimes we don't	27%
We always track field rework	73%

Data from the 15 companies that use QPMS

Table 3.7. “Which statement most accurately reflects your company's attitude toward field rework?”

Attitude Toward Field Rework	Response from Survey
A target of zero field rework should be set for all projects.	33%
There is an optimal zero or non-zero level of field rework that should be targeted, based on project characteristics.	60%
Field rework happens. It's simply not worthwhile to track it.	0%

Data from the 15 companies that use QPMS

As Tables 3.6 and 3.7 show, companies that use QPMS are more likely to always track rework and to set rework targets based on project characteristics. There are two ways of interpreting this result. It's possible that companies that were tracking rework and setting rework goals found QPMS beneficial and incorporated it into their procedures. Or, companies started

using QPMS and this lead to goal setting and increased their tracking of rework. Either way, the QPMS appears to be used by companies who require a system that will be used extensively.

Table 3.8 shows that process industries were more likely to use QPMS. Process industries include petrochemical, chemical, food, and paper products.

Table 3.8. “CII has developed a quality performance management system (QPMS) for measuring the cost of quality, which among other costs includes the cost of rework. What is your level of familiarity with QPMS?”

QPMS	Process Industry	Other Industries
Never heard of it	36%	57%
We have not tried it	30%	33%
We have tried it, but discontinued its use	2%	2%
We have borrowed and selected portions of the QPMS system	25%	5%
We use QPMS almost exactly as presented in CII Research Summary 10.3	9%	0%

As discussed earlier, it appears that projects in the process industry are more likely to experience some level of rework. With the greater potential for rework, the process industries have a greater need to incorporate some type of measurement system into their procedures. With this greater need, the QPMS has been used more in the process industry with 34 percent using all or portions of the system. Only 5 percent of the companies in other industries use it.

Section 4 of this report will discuss QPMS in more detail. The QPMS is set up to provide meaningful quality information at the lowest cost. But, with any system, there are a certain amount of resources that will have to be put into maintaining the system. If companies have a need to reduce rework, they should compare the benefits of reducing rework with the

minimal costs of maintaining QPMS. Section 4 discusses Company X's use of the system. Company X has significantly reduced rework with QPMS and has concluded that the benefits outweigh the cost of the system.

It is likely that companies that experience very low rework on their projects may not find it beneficial to incorporate QPMS into their procedures. Remember, 60 percent of respondents outside of the process industry, indicated that zero rework should be the target on all projects. If these companies are often achieving this goal of zero rework, then there would be no need to measure rework, QPMS or otherwise.

3.3 Respondents Who Sometimes Track Rework

On the survey 33 out of 85 respondents indicated that they "Sometimes track field rework, sometimes don't." These respondents were asked what factors determine if they track rework. Table 3.9 shows the results from this question.

Table 3.9. Factors that Affect Decision to Track Rework

Factors that Affect Decision to Track Rework	Response from Survey
Contractual arrangement for compensation	61%
Size of project	42%
Depends whether project is green field or remodel/retrofit	9%
Other factors	64%

The % of responses is based on the 33 who sometimes tracked rework; those who never or always tracked were not asked this question.

Some of the “other factors” included:

- “Measure rework on projects at risk for high rework”
- “Tracked on some projects to provide historical reference data”
- “Preference towards tracking rework, but program not fully implemented”
- “Measure rework on projects where it may affect schedule or cost”
- “Availability of resources and personnel to track rework”
- “Decision to track rework depended on who is on project (contractor, crafts, own work force or others)”

3.4 Respondents Who Never Track Rework

It was found that most respondents either always or sometimes tracked rework. However, there were 11 of the 85 respondents who indicated that they never track it. To understand why, those 11 respondents were asked to indicate why they don’t track rework. Table 3.10 shows the results from this question.

Table 3.10. Reasons Rework Is Never Tracked

Reasons Rework Is Never Tracked	Response from Survey
Expect that cost of tracking is greater than potential cost of savings	36%
Too many other things to do	36%
Nothing is ever done with the data	27%
Other responses	55%

The % of responses is based on the 11 who never tracked rework.

“Other responses” included:

- “Experience is that field rework is usually the result of poor front end planning/scope definition”
- “Strive to do it right the first time”
- “Better to try and prevent rework, than to track it”

As indicated by the survey, there are a number of reasons why companies may decide to track or not track rework. This research did not investigate the above factors. Instead the focus is on effectively measuring rework and using that information to reduce rework and improve operations. The end result may lead more companies to track rework.

3.5 Utilization of Rework Data

A rework measurement system can serve many purposes. At the very least, it is a communication tool to pass information along to various parties involved in the project. A change or deviation from the original work must be approved. The rework measurement system will provide a procedure for documenting the request and for receiving approval to proceed. Beyond this basic purpose, the system can assist the organization in other areas; areas such as assigning costs and improving their design and construction practices. To understand the current industry use of rework measurements the survey asked, “When you track field rework, what do you do with the information?” Respondents were allowed to select multiple answers. Table 3.11 presents a summary of responses.

Table 3.11. Use of Rework Information

Use of Rework Information	Response from Survey
Determine whether corrective action is needed	78%
Use to improve engineering	77%
Gather historical cost information for estimating / benchmarking purposes	62%
Recover costs from others on the design / construction team	47%
Others	36%

The % of responses is based on the 74 who sometimes or always track rework.

3.6 How Is Rework Minimized

The CII “Field Rework” research is directed towards the goal of minimizing rework. To learn about the current industry efforts to reduce rework, the survey asked respondents about how they minimize field rework.

Respondents were allowed to indicate multiple answers to the question regarding “Minimizing field rework”. Table 3.12 lists possible actions to take to reduce rework, and the percentage of respondents who use them.

Table 3.12. How to Minimize Rework

How to Minimize Rework	Response from Survey
Heavy emphasis on up front planning and scope definition	98%
Use of constructability programs	88%
Establishing rework goals at the beginning of the project	48%
Use of the PDRI (Project Definition Rating Index Explained in CII Research Summary 113-1)	31%

3.7 Who and How of Rework Measurement System

The following survey results focus on how companies have set up their rework measurement systems. The survey included questions focusing on who documents rework and how rework is categorized and collected. This provides information on the framework of current measurement systems in use. As will be shown in the following tables, there are many different ways to set up a measurement system.

3.8 Who Documents Rework

A basic requirement for the measurement system is to document the rework activities. As part of this system, specific personnel will have responsibilities to provide the needed information. As part of the survey, the question “Who has responsibility for recording costs of field rework?” was asked. The respondents were allowed to select multiple answers to this question. Results are shown in Figure 3.2.

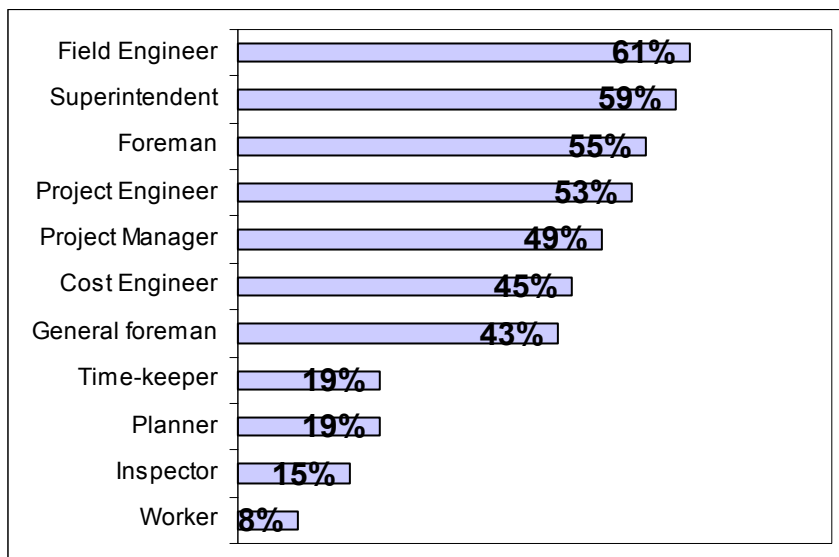


Figure 3.2. Percentage of Respondents Who Indicated the Listed Job Title Was Responsible for Recording Cost of Field Rework

As shown in Figure 3.2, there are several possible choices in selecting the personnel responsible for recording the cost of field rework. The survey provided no single clear answer to who should record the rework data. Instead, there are several job titles that received very similar response rates.

There are several factors to consider when selecting the personnel responsible for recording cost of rework. First, for the measurement system to function properly the data needs to be accurate. This requires someone either directly involved in the rework activities or someone who is in communication with the personnel carrying out the rework.

Second, the personnel collecting the data should be considered part of the team that uses the data to come up with improvement ideas. One of the goals for the rework measurement system should be for continuous improvement of the construction activities. The personnel recording the rework activities will be in a good position to provide suggestions for improvement.

A third factor to consider is the time requirement for recording field rework activities. The measurement system should be set up to minimize the resources needed to maintain the system, but nevertheless it will require some of the personnel's time. So, the personnel selected should be in a position to dedicate the necessary time to this activity. In addition, the personnel involved in recording the field rework activities must be given the necessary training in the system.

When considering these factors, the optimal personnel for recording rework activities will vary from company to company, or project to project. Each company will have to analyze their own situation to determine the best personnel to use to record the rework data in an accurate, continuous improvement-driven and cost-efficient manner.

3.9 How Rework is Categorized

The research team defined rework as, “activities in the field that have to be done more than once in the field or activities which remove work previously installed as part of the project”. Within this definition there are various ways of collecting and categorizing the rework. The questions and summarized responses presented in Tables 3.13 to 3.16 help the reader understand the current practices involved in measuring and categorizing rework.

Table 3.13. “What metric or measurements do you use to track field rework?”

Metric Used to Track Rework	Response from Survey
% of total installed cost	55%
% of direct labor	45%
Other metrics	28%

The % of responses is based on the 74 who sometimes or always track rework.
(Multiple answers were allowed)

Table 3.14. “How do you accumulate the cost of field rework?”

Accumulate Rework Cost	Response from Survey
a) Actual hours taken from time sheets	30%
b) Estimate based on scope of field rework items	19%
c) Both a) and b)	49%

The % of responses is based on the 74 who sometimes or always track rework.

Table 3.15. “How is rework tracked?”

Tracking Rework By:	Response from Survey
We track field rework by contract/subcontract	64%
We track rework by craft	57%
We track rework by work package	50%

The % of responses is based on the 74 who sometimes or always track rework.
(Multiple answers were allowed)

Table 3.16. “Tracking schedule impact of field rework”.

Tracking Schedule Impact	Response from Survey
We always track schedule of field rework	22%
We attempt to track the cumulative affect of numerous items of rework	72%
We do not attempt to track schedule impacts of rework	11%

The % of responses is based on the 74 who sometimes or always track rework.
(Multiple answers were allowed)

Similar to the question on “Who” should collect the data, the optimal way of “How” to collect the data can vary from company to company depending on their needs. There are several factors that each company should consider when selecting “How” to collect their rework data.

One factor to consider is what is to be done with the rework data. One focus of this research is that rework data can be used for continuous improvement. The data from the measurement system can provide information to direct improvement activities. The system must be set up to track data in such a way to provide meaningful data to accomplish the defined goals.

A second factor is that the system should be set up to minimize the costs of maintaining it. One way to do this is to base the system on data that is already collected. For example, in some cases it may be possible to take existing worker time sheets and collect information on rework activities. Or modify the existing worker time sheets to categorize rework activities. This eliminates the cost of setting up a completely new system to track rework.

A third factor is related to who is collecting the rework information. In Figure 3.2 information was presented on possible job titles that could be responsible for collecting data. The personnel responsible for collecting the data must have access to the information. For instance, if the rework measurement system is based on collecting data from time sheets, then the

personnel collecting the data must have access to worker time sheets. Or, if the rework data are calculated from estimates based on scope of field rework items, then the personnel responsible must have the training and experience necessary to determine the estimates.

3.10 Accuracy of Rework Data

If the data collected from a rework measurement system is going to be used in a meaningful way, then it is important for the system to have a high degree of accuracy. The survey asked respondents to estimate the accuracy of their measurement systems. The results of this question are presented in Table 3.17.

Table 3.17. “For projects where you track rework, what do you estimate the accuracy of reporting of field rework to be?”

Accuracy of Reported Rework	Responses from Survey
Less than 50% of actual rework is reported	23%
50-75% of actual rework is reported	32%
75-100% of actual rework is reported	43%
More than 100% of actual rework is reported	0%

The % of responses is based on the 74 who sometimes or always track rework.

One way of improving the accuracy of the data is to emphasize the importance of the data. If the information is used to reduce rework and improve operations, then stress this benefit to the personnel involved in the system.

3.11 Conclusions from the Industry Survey

The following conclusions are drawn from analysis of the industry survey of attitudes toward, and practices regarding, field rework:

1. Most CII companies have a tracking system, so they can use information from this report to benchmark their system and look for ways to improve their system. Eighty-seven percent either “always” or “sometimes” track rework.
2. Most CII companies agree with setting targets for rework. Ninety percent favor either a “zero” or “optimal non-zero” level of rework for a target.
3. Companies in the process industries are more likely to track rework and set a target based on project characteristics.
4. Most companies have not tried QPMS. Seventy-nine percent had “never heard of it” or have never “tried it”.
5. Very few of the companies that had used QPMS, discontinued it. Only two of the 17 companies who used the system discontinued it. They must be getting benefits out of the system.
6. Companies in the process industries are more likely to use QPMS. This is probably connected to this group tracking rework more.
7. Ninety-eight percent of respondents listed “Heavy emphasis on up front planning and scope definition” as a way to reduce rework. Companies can use the PDRI, CII research summary 113-1 (CII, 1997) to measure and improve up-front planning.
8. Seventy-seven percent of respondents used field rework data to “improve engineering”. This is one area for focus; a field rework measurement system should be used as part of a continuous improvement effort.

4.0 FOCUS GROUP

The members of the research team devoted considerable time and effort to developing a list of possible predictors of field rework to be used in the development of the Field Rework Index (FRI) envisioned by the research team. The list would be used to collect project specific data to validate whether in fact these variables were predictors of measured rework on actual projects. In an attempt to make the data collection as efficient as possible, and to encourage maximum contribution of projects to the database, the research team planned and executed a focus group of construction industry experts in field rework from outside the research team. The objective was to develop the best list of rework predictors possible.

4.1 Procedure

The industry survey had requested volunteers for a field rework focus group. Invitations were extended to a small group of volunteers representing a desirable mix of diverse owner, designer, and contractor viewpoints. The group was designed to be no larger than ten to 15 individuals in order that free exchange of ideas and information would be encouraged. The focus group of six industry experts, a construction industry facilitator, and the principal investigator for the research project were convened on February 18, 1999, in Houston, Texas. Although this group was smaller than intended due to last minute cancellations, it did provide a diverse group of experts. Table 4.1 summarizes the make-up of the focus group.

Table 4.1. Focus Group Participants

Participant	Industry
Owner	Petrochemical
Owner	Petrochemical
Construction Contractor	Process
Design Contractor	Process
Design/Construct Contractor	Process
Owner	Petrochemical
Construction Contractor*	Process

* Facilitator

4.2 Data

The starting point for the focus group was the list developed by the research team. The structured discussions resulted in additions to, deletions from, and prioritization of the list. This information was subsequently reviewed and discussed by the research team.

The focus group ranked the abilities to predict rework of the list of potential predictors as “low” (1), “medium” (2), and “high” (3). The research team rated the variables from very low (1) to very high (5). Appendix B shows the ratings by the research team and the focus group for the potential predictors. Also shown is a composite normalized rating obtained by dividing the research team score by the maximum score of 5, and adding it to the focus group score divided by the maximum score of 3. The variables are presented from highest composite score (rank 1) to lowest composite score (rank 61).

A list of additional potential predictors emerged from the focus group and subsequent research team discussion. These items were not ranked, but were submitted for potential

inclusion in the data collection instrument for the compilation of the database. These possible predictors are presented in Table 4.2.

Table 4.2. Potential Predictor Variables Added by Focus Group and Research Team

Potential Predictor Variables
1. Approximate % of construction hours by discipline
2. Demand for craftworkers versus availability
3. Relative size of project for design firm (large job for office to small job for office)
4. Amount of design effort expended outside of U.S.
5. Extent of use of "contract" designers by design firm
6. If not 3D-CADD, level of interdisciplinary squad checks (QC & checking procedures)
7. Attitude of project team toward use of CII Best Practices or IPA VIP's (avid supporters ...to... no knowledge or interest)

4.3 Analysis

The ten potential predictors of field rework receiving the highest ratings from the focus group and from the research team are listed in order of descending importance below:

1. The degree to which engineering is complete at the start of construction
2. Whether 3-D CAD is used or not
3. The level of "front-end loading" for the project
4. Design team qualification and experience
5. Late receipt of certified drawings
6. Degree of design schedule compression
7. Degree of preplanning of construction
8. Design firm qualification and experience
9. Whether the project is "green field" or revamp/retrofit

The list of possible predictors and associated rankings represent the opinions of experienced practitioners of industrial construction. As such this information is valuable. But these were just opinions. The next step was to gather information from actual projects to determine if project data verified or refuted the list of possible predictors. The potential predictors of Appendix B that received high ratings from both the focus group and the research team and the potential predictors added after the focus group (Table 4.2) formed the basis for the formulation of a data collection instrument to be used to compile a database of project data. The compilation of the database and its analyses are described in Chapter 5.

5. PROJECT DATABASE

The research team envisioned an end product of the research that would provide an early warning if a project is headed toward high levels of field rework. This early warning tool would be called the field rework index (FRI). It was to be used before the start of construction.

The research team and focus group (Chapter 4) had developed a list of possible predictors of field rework, henceforth called variables, which they believed could be used to predict levels of field rework. The next step was to test these variables with data from completed construction projects.

5.1 Compiling the Database

The distilled list resulting from the focus group and subsequent research team review was incorporated into a data collection instrument for the compilation of a project database. The database would be used for development of the FRI. This data collection instrument is displayed in Appendix C. The list of 44 possible predictor variables shown in Part C of the form reflects adjustments to the list from Appendix B and Table 4.2. The principal investigator, with review comments from research team members, pared the list to 44 based on factors such as likelihood of relationship, ability to rank, and overlap with other variables.

The objective was to collect actual project measured field rework data from completed projects, and to have project participants retroactively score the variables identified by the focus group and research team. Regression analysis would be performed to determine whether relationships existed between the possible predictor variables (independent variables) and field rework (dependent variable). Part B of the data collection instrument (see Appendix C) requested the actual field rework measurements. Part A of the form gathered general information about type of project and other parametric data.