Executive Summary

Measuring and Classifying Construction Field Rework: A Pilot Study

Aminah Robinson Fayek, Ph.D., P.Eng.
Manjula Dissanayake, Provisional Ph.D. Candidate
Oswaldo Campero, M.Eng.

Department of Civil and Environmental Engineering
University of Alberta

May 2003

Presented to:

Construction Owners Association of Alberta (COAA)
Field Rework Committee

DISCLAIMER

The information in this research report is provided only as a guide for full-scale studies. All the data are project specific and thus cannot be used to draw conclusions that relate to different projects, companies, or industry-wide scenarios. The views expressed and the conclusions reached in this report are those of the authors and not necessarily those of the persons consulted. The University of Alberta and the authors shall not be responsible in any way whatsoever for any misuse or misinterpretation in whole or in part of the contents of this report.

Available on Website

The Field Rework Data Collection System (database), Executive Summary, and full report, *Measuring and Classifying Construction Field Rework: A Pilot Study*, are all available on the following websites:

http://www.coaa.ab.ca
http://www.construction.ualberta.ca/papers.html

To obtain additional information, please contact:

Aminah Robinson Fayek, Ph.D., P.Eng.
Associate Professor
Department of Civil and Environmental Engineering
220 Civil/Electrical Engineering Building
University of Alberta
Edmonton, Alberta
T6G 2G7
Canada
Phone: (780) 492-1205
Fax: (780) 492-0249
E-mail: arobinson@civil.ualberta.ca

ACKNOWLEDGEMENTS

Many individuals participated in this project. This study is a result of the collective efforts of the Field Rework Measurement Subcommittee and the Pilot Study Steering Committee of the Construction Owners Association of Alberta. Special acknowledgement is given to the following people for their continuous guidance and support throughout the pilot study:

Don McLeod (Co-Chair of Field Rework Committee)	SNC Lavalin
Hans Wolf (Chair of Measurement Sub-committee)	Graham Industrial
Daniel Meek	TransCanada Pipeline
Glen Warren	Ledcor Industrial
John Hull	
Rod Wales	North American Enterprises

Additionally we would like to express our appreciation to Don McLeod (Co-Chair of Field Rework Committee) who provided many forms of assistance, but best of all always kept us in good spirits through the completion of this pilot study. We also appreciate the invaluable support provided by the Syncrude Aurora 2 project team throughout the data collection period. Their support in terms of providing access to the data and resources, and their full cooperation and knowledge sharing were key to the success of this study. Anthony Van Tol, a Ph.D. Candidate at the University of Alberta, was involved in the early part of this study; his contributions are gratefully acknowledged.

Special thanks are directed to NSERC and the Consortium of Alberta Construction Companies, COAA, Aurora 2 Project Group, and the Construction Research Institute of Canada, for their financial support.

LIST OF ABBREVIATIONS

CFRI	Construction Field Rework Index
CII	Construction Industry Institute
COAA	Construction Owners Association Of Alberta
EPC	Engineering, Procurement, and Construction
FRDCS	Field Rework Data Collection System
IFC	Issued-For-Construction
PMI	Project Management Institute

EXECUTIVE SUMMARY

1.0 PROBLEM STATEMENT

(Refer to Section 1.1 in full report)

The Alberta Construction Industry is currently undergoing rapid growth, particularly in the industrial sector. Several mega-projects are currently underway. With tight schedules and multiple parties involved, cost and schedule overruns are often difficult to avoid. One contributing factor is rework.

The COAA has therefore established a goal of developing industry Best Practices for reducing and preventing construction field rework. The Field Rework Committee was subsequently established to facilitate the development of these Best Practices. Before rework can be reduced and prevented, however it must first be quantified, measured, and its root causes identified. The Field Rework Measurement Subcommittee was created and charged with this mandate.

Despite the fact that numerous studies have been conducted on rework, there is still no industry-wide standard for measuring and classifying rework as it occurs in the field. Currently, different organizations track rework using different indices, making it difficult to compare the amount of rework on an industry-wide level. Furthermore, an industry-wide method of classifying the causes of rework is required, before the most significant causes can be identified and subsequently remedied.

2.0 OBJECTIVES OF PILOT STUDY

(Refer to Section 1.2 and 2.2 in full report)

The overall objective of the COAA Field Rework Committee is to develop industry Best Practices for reducing and preventing construction field rework. As a first step, a methodology was required to measure and quantify field rework, and identify the most significant causes of rework. A pilot study was commissioned with the University of Alberta to develop and test such a methodology.

The specific goals of the pilot study were as follows:

- To develop a definition for construction field rework.
- To develop a standard rework index for quantifying the amount of field rework on a project.
- To develop a standard methodology for identifying rework in the field and measuring or quantifying the amount of rework on the basis of cost, schedule, and other impacts.
- To develop a realistic classification of the major factors and sub-factors causing rework, and to develop a standard definition of each factor.
- To develop a standard methodology for quantifying the impact of each cause on the rework amount.
- To develop a methodology for assessing the impact of rework from a given activity on other affected activities in the project.

- To develop a standard methodology of tracing the cause(s) that led to rework, from the original source.

The intent of the pilot study was to help develop and refine the research methodology for collecting and quantifying field rework data, before a full-scale study is undertaken involving numerous projects.

Since the pilot study is being conducted on a mega-project performed under an EPC arrangement, the results of this study are likewise geared towards similar types of projects.

3.0 COMPONENTS OF PILOT STUDY

(Refer to Section 4.0 in full report)

3.1 Proposed Field Rework Definition

(Refer to Section 4.1 in full report)

This pilot study started with the COAA definition of field rework (COAA, 2001), as this work builds on efforts put forth by the COAA based on this definition. As the study progressed, the researchers identified the need for a more detailed definition of rework in order to clearly indicate what is and what is not considered rework from the owner's perspective or from the point of view of the whole industry.

Accordingly, we have adopted and modified the CII's (2001) definition, and 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 regardless of source, where no change order has been issued and no change of scope has been identified by the owner.*

Furthermore, field rework is not:

- Project scope changes.
- Design changes or errors that do not affect field construction activities.
- Additional or missing scope due to designer or constructor errors (but rework does include the cost associated with redoing portions of work that incorporate or interface with additional or missing scope).
- Off-site fabricator errors that are corrected off site.
- Off-site modular fabrication errors that are corrected off site.
- On-site fabrication errors that do not affect direct field activities (i.e., that are corrected without disrupting the flow of construction activities).

Project Scope is "the work that must be done to deliver a product with the specified features and functions" (PMI, 2000). Any change to the project scope (i.e. scope changes) should not be considered as field rework. These "changes may require expanding the scope or may allow shrinking it. Most change requests are the result of: (1) An external event (e.g., a change in a government regulation); (2) An error or omission in defining the scope of the product (e.g., failure to include a required feature in the design of a telecommunications system); (3) An error or omission in defining the scope of the project (e.g., using a bill of materials instead of a work breakdown structure); and (4) A value-adding change (e.g., an environmental remediation project is able to reduce costs by taking advantage of technology that was not available when the scope was originally defined)" (PMI, 2000).

Rework costs are tracked from the point where rework is identified to that time when rework is completed and the activity has returned to the condition or state it was in originally. The duration of the cost tracking includes the length of the standby/relocation time once rework is identified, the time required to carry out the rework, and the time required to gear up to carry on with the original scope of the activity. The sequences of events that constitute rework are shown in Figure 3.1.

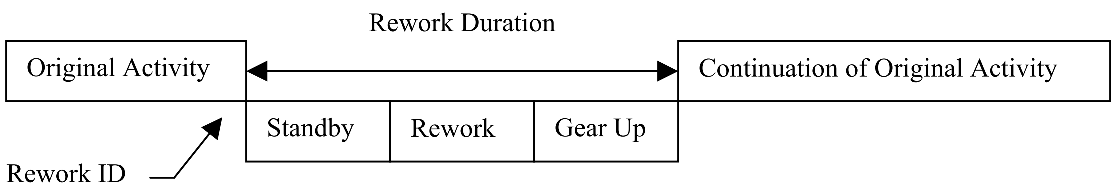

Figure 3.1. Components of Rework

3.2 Proposed Construction Field Rework Index (CFRI)

(Refer to Section 4.2 in full report)

An established field rework measurement system is necessary for a project to see if it meets the targets set and/or to provide a basis for future improvements. The following index is used in the pilot study to measure rework:

$$\text{CFRI} = \frac{\text{TOTAL DIRECT PLUS INDIRECT COST OF REWORK PERFORMED IN THE FIELD}}{\text{TOTAL FIELD CONSTRUCTION PHASE COST}}$$

$$= \frac{D_r \times I_f}{[D_t + I + P + O]} \qquad [3.1]$$

Where,

D_r = Total direct field cost of rework

$$D_r = \Sigma_1^n \; l_{r_i} + e_{r_i} + m_{r_i} + s_{r_i} + v_{r_i} \qquad [3.2]$$

l_r = Direct field labour and supervision cost of rework

e_r = Direct equipment cost of rework

m_r = Material cost of rework

s_r = Subcontract cost of rework

v_r = Vendor's and supplier's cost of rework

i = rework event

n = Number of rework events

$$I_f = \frac{D_t + I}{D_t} = \text{Field indirect markup factor} \qquad [3.3]$$

D_t = Direct field construction phase cost

I = Indirect field construction phase cost

P = Profit fees($)

O = Overhead fees($)

In equation 3.1, the numerator is defined as the sum of the direct and indirect field rework costs. The direct field cost of rework is a combination of the following, which can be attributed directly to the corresponding scope of work: (1) direct field labour and supervision - l_r, (2) materials - m_r, (3) construction equipment - e_r, (4) field contracts (subcontracts) - s_r, and (5) vendors' and suppliers' cost - v_r. The sum of the total direct and indirect costs of rework is calculated using a mark-up factor (equation 3.3) that is applied to the direct field cost (equation 3.2) in order to account for the indirect field cost. Field and/or office re-engineering costs associated with rework are not considered a direct field cost, but are included in the indirect field costs. The denominator consists of the total construction phase cost, which is a combination of: (1) direct field costs, (2) indirect field costs, (3) contractor overheads, and (4) contractor profit (see Appendix D in full report for details of cost inclusions). The denominator includes costs associated with the original scope of work plus costs associated with changes in scope and costs associated with rework. The total construction phase cost excludes original design and engineering costs, but includes field engineering and re-engineering during construction.

For cost reimbursable contracts, in the case where s_r and v_r are back-charged to the subcontractor, they should be accounted for in the numerator, and in the denominator if the contract value increases. For lump sum contracts, the option exists to include back-charged costs of rework in the numerator, but not modify the denominator if the cost of the contract does not change.

3.3 Proposed Rework Classification System

(Refer to Section 4.3 in full report)

The classification system proposed in this research for categorizing the causes of rework is based on the fishbone classification system (so-called because of its shape) developed by the COAA. The COAA used the fishbone diagram (technically called the Cause & Effect (CE) diagram) to explore all the potential or actual causes of rework. The fishbone consists of five broad areas of rework and four possible causes in each of these areas. As the study progressed, the COAA's original fishbone was modified with the approval of the COAA Field Rework Committee to overcome some of the anomalies identified by the researchers. Figure 3.2 shows the fishbone diagram at the conclusion of the pilot study. Previous versions of the fishbone diagram are given in Appendix F of the full report.

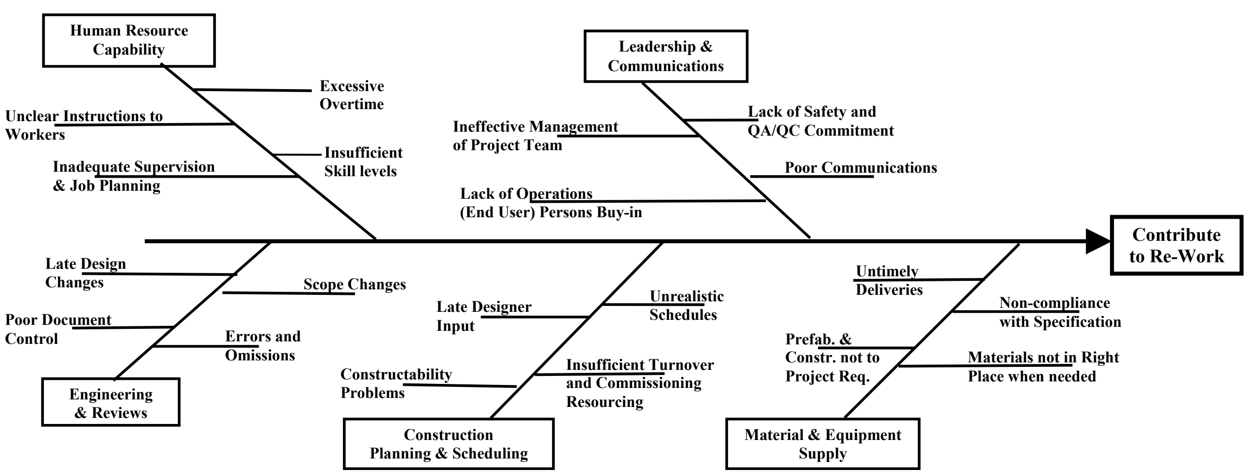

Figure 3.2. COAA's Fishbone Rework Cause Classification (last updated October 2002)

Furthermore, our efforts have generated a third classification level specifically for rework causes (see Appendix F of the full report for details). It was decided that this additional level provides the best degree of classification detail, after which its complexity exceeds its effectiveness. The third level factors for the “Engineering and Reviews” category were reconciled with those developed by the Engineering and Reviews Rework Subcommittee.

In some cases, there are several root causes that lead to a rework incidence. A standard approach is proposed for attributing multiple root causes to a rework item, and apportioning these causes to the resulting rework item (refer to Section 4.4 of full report for detailed discussion).

3.4 Field Rework Data Collection Methodology

(Refer to Section 4.5 in full report)

The field rework tracking process shown in Figure 3.3 was used in the pilot study to monitor field rework events. The field rework tracking process starts when an incidence is identified in the field, which involves rework as per the definition cited previously.

The site personnel who usually identify these incidences are: (1) Workforce, (2) Foreman, (3) Field technical personnel, (4) Field engineer, and/or (5) Quality control personnel. Depending on the incidence, they report it to the respective authority (e.g. Field engineer, Quality control, Field technical) to obtain instructions. The instructions can be separated mainly into two categories: either to redo it or to accept it as is. If the relevant authority decides to redo the work, they have to issue instructions on how and when to do so. Necessary resources are assigned accordingly, and the rework is carried out.

Rework event information is collected by observing the event, time sheets, and/or by interviewing the construction personnel. Firstly, event information is obtained from the field as reported in the “Field Rework Data Collection Form” (see Appendix E of the full report for sample data collection forms and a worked example). Secondly, this information is transferred to the “Rework Event Information Sheets”, which are given in the same Appendix E, in order to determine the direct cost of the rework event. Finally, as shown in the Section 3.2, event data are aggregated according to Equation 3.2, and the Construction Field Rework Index (CFRI) is constructed using Equation 3.1.

Root causes of the rework events were identified by interviewing relevant parties involved in the rework event. Once the causes were identified, researchers classified those causes according to the methodology described in Section 3.3.

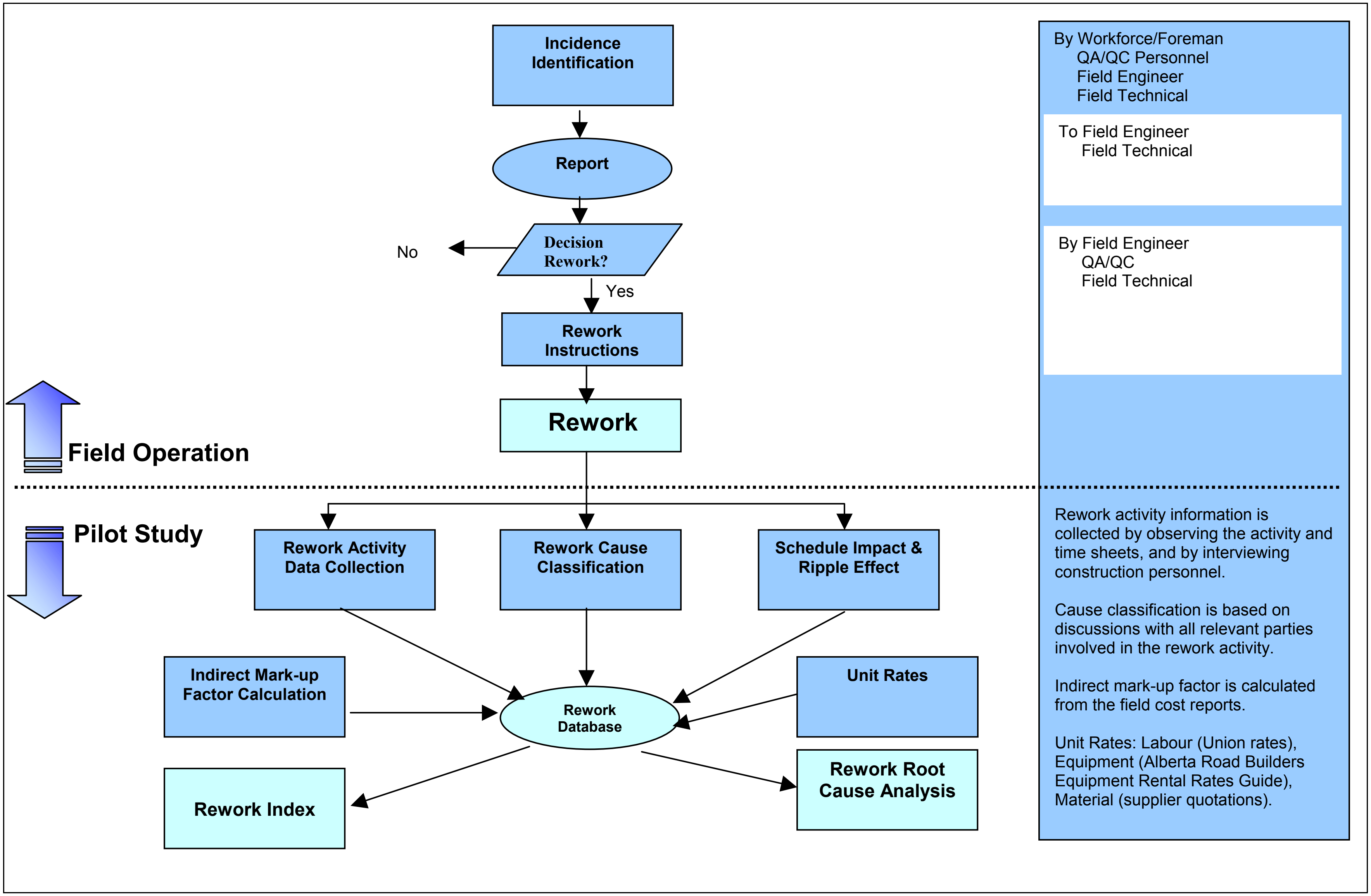

Figure 3.3 Field Rework Tracking Process for Pilot Study

3.5 Field Rework Data Collection System (FRDCS)

(Refer to Section 4.6 in full report)

To facilitate the proposed methodology, a Field Rework Data Collection System (FRDCS) was developed. The FRDCS is a database built using Microsoft® Access 2000 with a Microsoft® Visual Basic 6.0 interface. Figure 3.4 shows the main screen of the FRDCS. The FRDCS is divided into three modules: (1) data entry (2) rate definition, and (3) data retrieval.

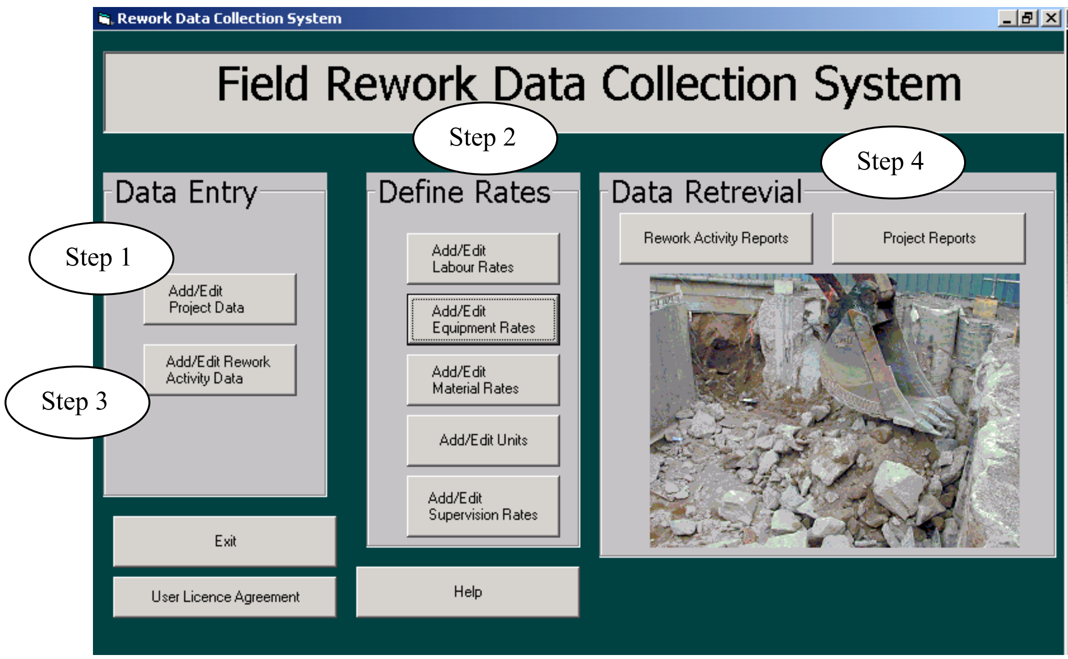

Figure 3.4. Main Screen of the Field Rework Data Collection System (FRDCS)

Firstly, the user enters project-specific data into the system, such as actual direct field costs, indirect field costs, overhead fees, and profit fees (Step 1). This information is used to calculate the field rework index denominator. Secondly, the user defines the rates and units applicable for the particular project (Step 2). This allows the user to select the relevant rates and units from the database when activity information is recorded. Once the first two steps are completed, the user can start recording rework activity data (Step 3). Rework activity information consists of three sub-sections: (1) general activity information, (2) cost information, and (3) cause classification data. The cost information sub-section allows the user to provide labour, supervision, equipment, material, subcontract, and vendor costs associated with the rework incidence. The data retrieval section of the main menu (Step 4) allows the user to generate reports of the rework event information, and the summary information of all rework activities, i.e. the Construction Field Rework Index (CFRI) and the field rework cause classification. According to the procedure described above, the FRDCS allows an organization to keep records of the rework incidences as they occur, to construct the Construction Field Rework Index (CFRI), and to identify the root causes of field rework. Alternatively, the user can use the data collection forms given in Appendix E of the full report to manually keep these records.

4.0 CASE STUDY: SYNCRUDE AURORA 2 PROJECT

(Refer to Section 5.0 in full report)

A case study of an actual project was used to verify the methodology and to collect a sample data set with which to illustrate its application. The Syncrude Aurora 2 Project in Fort McMurray, Alberta was selected as a case study. Aurora 2 is a mega-project, performed under an engineering, procurement, and construction (EPC) arrangement, with an estimated cost of $599.6 million Canadian dollars. It consists of a mining expansion to process 58 million t/a of ore to provide 38 million bbl/yr of feedstock for a related upgrader expansion project (UE-1). The project is a cost reimbursable project, which is part of an Alliance contract consisting of AMEC Engineering and Construction Services Limited (design/engineering), TIC Canada (structural/mechanical), Chemco Electrical Contractors Limited (electrical), North American Enterprises Limited (civil), and Syncrude Canada Limited (owner). All parties involved are working together under an agreement of full disclosure of information.

The project selection was based primarily on the suitability of the project type, which is reflective of major industrial projects in Alberta, and on the availability and willingness of the Aurora project group to participate and provide in-kind funding for the pilot study.

4.1 Data Collection and Analysis

(Refer to Section 5.3 in full report)

The data collection period for the pilot study was from April 29th, 2002 to December 19th, 2002. During this period, 125 field construction rework incidences (CRW's) were collected for the analysis. The pilot study analysis consisted of: (1) calculating a field rework index for the rework incidences collected during the study period; (2) classifying each of the 125 CRW's accordingly using the fishbone classification system provided by the COAA; and (3) evaluating various information obtained from the "Field Data Collection Form".

For the purpose of the pilot study, neither EPC contracts nor back-chargeable costs were included in the construction field rework index (CFRI) calculations. The main reasons for this exclusion were: (1) there was not sufficient detailed information relative to the field rework costs performed by the subcontractors and/or EPC contractors, and (2) the lump sum amount of the work subcontracted and/or performed under EPC contracts was relatively insignificant as compared to the total project construction phase cost. Consequently, the CFRI calculated for the project is based on 95 rework incidences (rather than 125).

4.2 Construction Field Rework Index (CFRI)

(Refer to Section 5.4 in full report)

The Construction Field Rework Index is a percentage value that determines the amount of field rework on a construction project. It is the result of equation 3.1 shown in Section 3.2. During the study period (April 29th, 2002 – December 19th, 2002), a rework index was determined based on the overall data collected and the actual figures obtained from the project's cost control system and from field data collection. The CFRI for the overall Alliance was 0.87%, which is based on 95 rework incidences. The civil work's rework index was 1.01%; the structural/mechanical work's index was 0.94%; and the index of the electrical work was 0.09%. The relatively low rework index for electrical work occurred as a consequence of the relatively low level of construction activity for this contractor during the study period. These rework indices represent only a snapshot of the project during the pilot study period. They cannot be considered a definitive number due to the fact that the pilot study finished before final project completion. Also, the associated costs of previous rework incidences prior to the pilot study period were not included in the calculation.

4.3 Field Rework Classification

(Refer to Section 5.5 in full report)

A root cause analysis of the 125 field rework incidences collected during the pilot study was performed (see Section 5.5.1 to Section 5.5.3 of the full report for a detailed discussion). Three different analyses are presented to illustrate the contribution for the subsequent root causes based on:

1.0 Contribution to the overall rework incidences relative to the other causes based on frequency of occurrence (i.e. relative contribution).
2.0 Frequency of occurrence of each rework cause within its category (i.e. absolute contribution). The FRDCS's output is based on this type of analysis.
3.0 Dollar-value magnitude (i.e. monetary value) of each rework incidence.

The values shown in Figure 4.1 illustrate the percent contribution of the first level causes, based on their frequency of occurrence, to the overall rework occurrences.

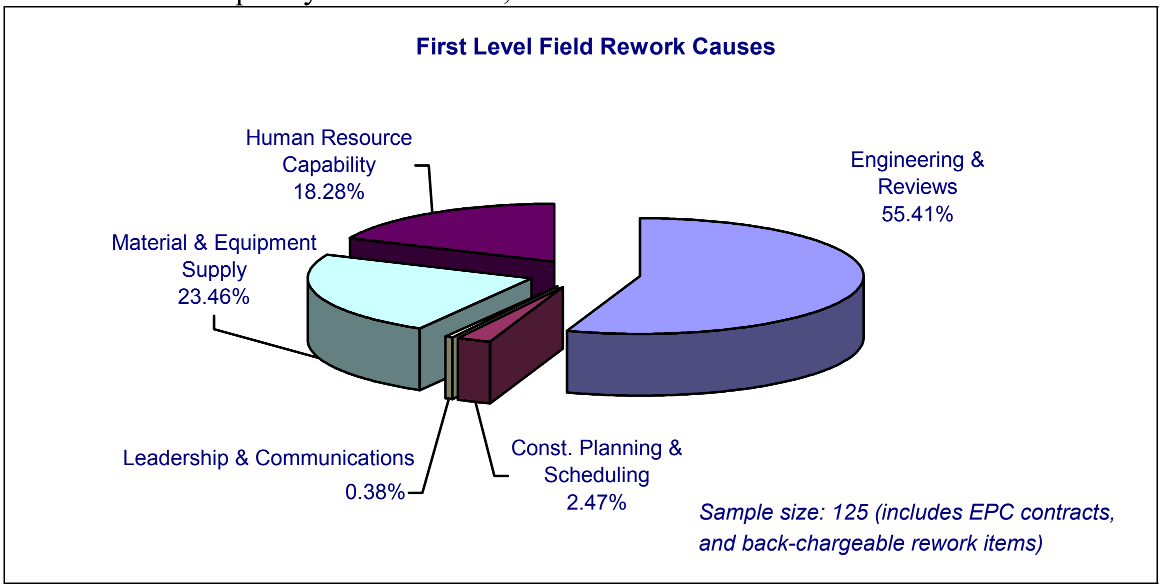

Figure 4.1. First Level Field Rework Cause Classification (based on frequency of occurrence)

The significance of rework causes is not only demonstrated by the frequency with which they occur, but is also obvious in the total resulting cost. Figure 4.2 illustrates the percentage contribution of the total cost of field rework as per the five major causes. The contribution of the actual dollar values of each first level cause is given in Figure 4.3. In this calculation, unlike the CFRI calculation, EPC contracts and back-chargeable costs, for which data were available, were included in order to increase the sample size.

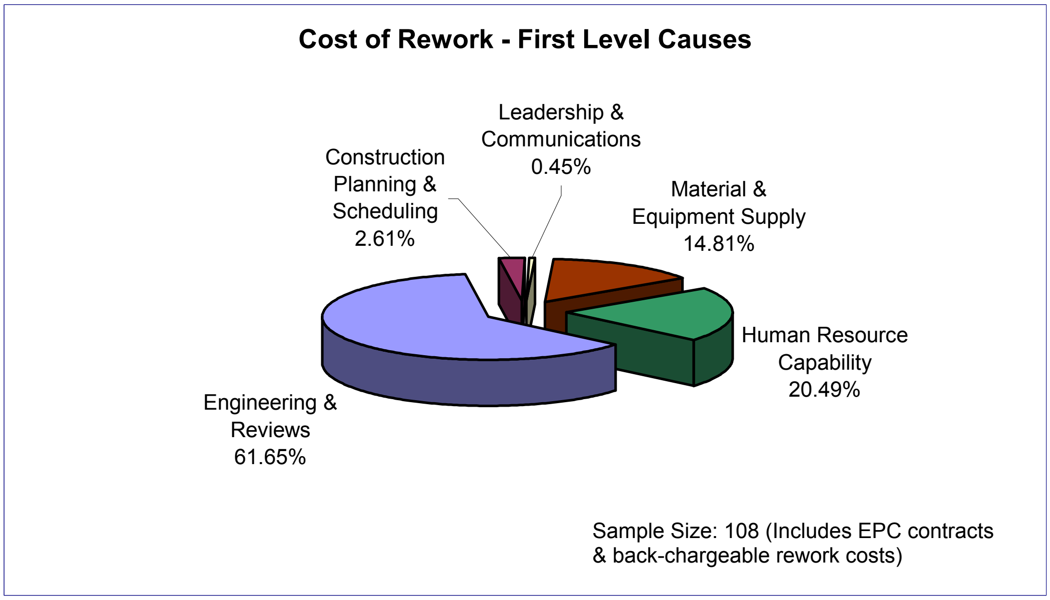

Figure 4.2. Rework Cost Contribution – First level Causes

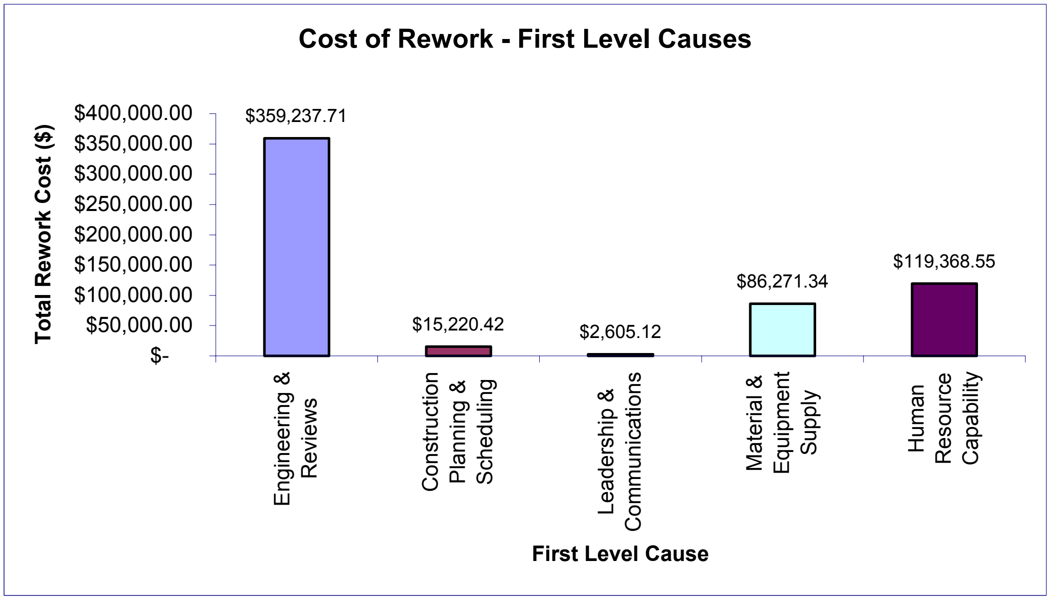

Figure 4.3. Total Rework Cost by Causes – First Level Causes

5.0 LESSONS LEARNED AND RECOMMENDATIONS FOR FUTURE STUDIES

(Refer to Section 6.3 in full report)

The proposed methodology for measuring, quantifying, and classifying construction field rework proved to be very effective. The categorization of the field rework was broken down into five general areas. These areas were further explored in order to obtain a more precise delineation of causes within quite specific levels (third level). The intent of this methodology is to establish which root causes contributed most to field rework, and to obtain an index for field rework in order to quantify the magnitude of costs associated with rework on a given project. The output of the proposed methodology provides an indication of the extent and magnitude of rework on a project, and those factors which most contributed to rework, enabling their eventual remedying.

Based on the pilot study results, it is evident that an increased emphasis is needed during the project's design and engineering phases to avoid further field rework during the construction stage. One important measure that can be taken to minimize rework is the development of improved design/engineering review standard procedures, such as value engineering, squad checks, etc., and the provision of increased time and resources in order to fully review and check all engineering milestones, especially in fast-track type projects.

Field engineering should have a designated person who reviews the newly released drawings "Issued for Construction" (IFC) in order to prevent any field inconsistency prior to construction. This person should carefully double-check all specifications and designs to verify their compatibility with actual project construction (especially when adopting the same design from a previous project). Companies should invest in allocating such a person, who will have access to all engineering disciplines from the start to the end of the project. This person would represent the closest link between construction and engineering, and would work with the rework coordinator.

Numerous rework incidences occurred on site while fixing errors originally made in the fabrication yard. There should be an effective and timely communication between field personnel and the fabrication yard in order to discuss any field changes that could lead to rework. For example, if a change occurs on the field, the fabrication yard should be immediately informed about this change, and then make such modifications as are necessary to avoid sending a wrong piece of material that would need to be fixed on site.

To record cost information and the causes of rework, there should be a predefined rework tracking process in place. The purpose of such a well-defined tracking system is to record cost information and rework causes specifically as rework occurs in the field. This system should be developed and maintained by an individual specifically assigned for this task (i.e. data collection, reporting, and monitoring field rework data). The costs and hours for each field rework incidence detected on site should be based on actual costs and hours counted through the rework initiator's administration system. The rework cost tracking system should also be built in such a way so that it enables all parties involved to take prompt action in order to manage construction rework (i.e. preventive measures, cost forecasts, lessons learned, etc.). Also, it should be updated and distributed to the concerned parties periodically. Maximum benefits can be achieved by implementing the system at the beginning of the field construction activities. This implementation could be achieved by making the reporting and monitoring of rework incidences a requirement or partial requirement of the contractual agreement.

Rework cause classification should be an unbiased process. The field rework coordinator should consult all parties involved in the incidence, before classifying rework causes and apportioning percentages. The field rework coordinator should have access to information at both field and engineering management levels.

The project's contractual agreement (Alliance concept) was the key element among those factors that contributed to the success of this pilot study. This is because all parties are responsible for the success of the project. Consequently, information and rework data were available to all Alliance partners. Sometimes, under different contractual agreements, some information is retained in order to avoid any further penalizations or loss of profits; however, with the Alliance concept, that is, the team concept, many of these issues do not exist. The effectiveness of a rework tracking process is greatly enhanced through the Alliance or partnership concept.

Another factor that contributed to the success of this pilot study was the pre-study preparation. This included the preparation of the preliminary field rework tracking forms after an intensive study of rework tracking processes. As the study evolved, a simpler form was developed, in addition to the more detailed forms. Based on these forms, a database was created to automate the storage and retrieval of rework data on future projects.

Finally, the involvement of the personnel on the Aurora 2 project and the involvement and feedback of the Pilot Study Steering Committee ensured that all technical matters that arose were discussed and addressed. This feedback ensured that the decisions made to deal with ambiguities over the course of the study were in line with the COAA's vision for standardizing field rework tracking.

The following challenges were encountered in this pilot study:

- *Schedule Extension:* The case study's project schedule was extended several times, thus affecting the data collection period. The initial scope of the pilot study was to record all information in one area from start to finish and thereby compile a valid figure for the rework index. Due to schedule extensions, however, the scope of data collection was expanded to encompass all areas of the project. Since the pilot study period concluded before the entire project was complete, the values obtained for the field rework index are not meaningful unless they are re-calculated upon project completion.
- *Subjectivity of Cause Classification:* Classifying rework causes in the third level, and attributing multiple root causes to a single rework event, is a fairly subjective process. Classification decisions may vary based on the differing criteria and

perspectives of each individual. Generally, there is a consensus as to the first level of classification, but subjectivity increases with increasing levels of detail. The proposed systematic approach to the classification of multiple root causes, attempts to reduce some of this subjectivity.

6.0 CONTRIBUTIONS AND EXTENSION OF THE STUDY

(Refer to Section 7.0 in full report)

One of the most significant contributions arising from this study is the thorough analysis and treatment of the field rework issue. In attempting to address this issue, researchers faced a number of ambiguities that were subsequently resolved with industry input, thus bringing further definition to the standardization of the definition, quantification, and classification of field rework. Standardization is critical for repeating, predicting, and comparing any measure, such as the Construction Field Rework Index and classification system.

As a result of this study, the following contributions are offered to the construction industry for use as extensions of this study:

1. A clearer definition of construction field rework.
2. A proposed index for quantifying construction field rework, as well as a clear definition of the components of this index.
3. A detailed 3-tier classification system for the causes of rework, and a systematic approach for apportioning multiple root causes.
4. A detailed approach to collecting field rework data, including a set of data collection forms.
5. A database in which to store the data collected, for the automated analysis of rework data and report generation.

While the objectives of the pilot study have been achieved, the real value of the work done is in these extensions. In order for the construction industry to benefit from this research, these standards and this methodology must be used over time to populate the database with the data of multiple projects. In this way, meaningful field rework indices and root cause classification results will arise. With these trends, the construction industry can formulate strategies to deal with the most significant causes leading to field rework. In addition, benchmarking both within organizations and for the industry as a whole can be done to measure and ultimately reduce field rework. Finally, this methodology can be modified and extended to the engineering phase of a project, and similar studies can be conducted for engineering rework.

The methodology developed in this study can be used as an industry Best Practice for measuring and classifying construction field rework. The next steps are to use this methodology over time and to collect sufficient data, from which the industry can develop a Best Practice for minimizing and preventing construction field rework and eventually engineering rework.

REFERENCES

Construction Industry Institute (CII). 2001. The field rework index: Early warning for field rework and cost growth. Research Summary 153-1, Construction Industry Institute, University of Texas at Austin, Austin, TX.

Construction Owners Association of Alberta (COAA). 2001. Meeting Minutes. September 28, 2001.

Project Management Institute (PMI). 2000. A guide to the project management body of knowledge (PMBOK guide). 2000 Edition.

Robinson Fayek, A., Dissanayake, M., Campero, O. 2003. Measuring and classifying construction field rework: a pilot study. Department of Civil and Environmental Engineering, University of Alberta. Presented to the Construction Field Rework Committee, Construction Owners Association of Alberta, May 2003.