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Root Causes & Consequential Cost of Rework

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This paper evaluates the impact of rework on direct and indirect construction cost for project types, project industry, and project size and procurement methods in various categories. By recognizing the impacts of rework and its sources, the construction industry can reduce rework and eventually improve project schedule and cost performance.

Section 1
Definition of Rework

Rework is defined as work measures that have to be completed more than once. Burati J.L. et al. (1992) described rework as a “non-conformance;” Peter E.D. Love[1] characterized rework as the “unnecessary process of redoing a work activity that was incorrectly carried out the first time.” Another definition which emphasizes the essence of rework is “work that is made to conform to the original requirements by completion or correction at least one extra time due to non conformance with requirements.” Rework is not commonly described to include missing scope of work changes and change orders brought about by end users/owners, which are **not** necessarily considered non-conformance. Rather changes such as these instead stem from a desire to change due to budget constraints or other unrelated circumstances.

Section 2
Introduction

Rework is a major contributor to cost and schedule. In a large complex environment that involves multiple levels of trades, suppliers and installers, and where many activities take place simultaneously, the likelihood for errors, omissions and poor management practices often cause neglect that can lead to quality failures, which must then be reworked. Errors are defined as unintended deviations from correct and acceptable practices and lead to project cost and schedule overruns, which are both unnecessary and avoidable. Five major areas of rework have been identified in the past by the Construction Industry Institute (1989), Peter E.D. Love (1990), and Burati J.L (1992) in which they state that design, construction, fabrication and transportation and operability were the causes of rework; sources of rework are described in Section 3.0. In addition to activities and sources previously described, the analysis of sample empirical independent research data from a variety of construction and engineering projects typically measures the cost of rework based on project type, project industry, project size and by procurement method. These data analyses are based on both direct and indirect costs that are attributable in the infrastructure and building industries. Section 6 considers these effects.

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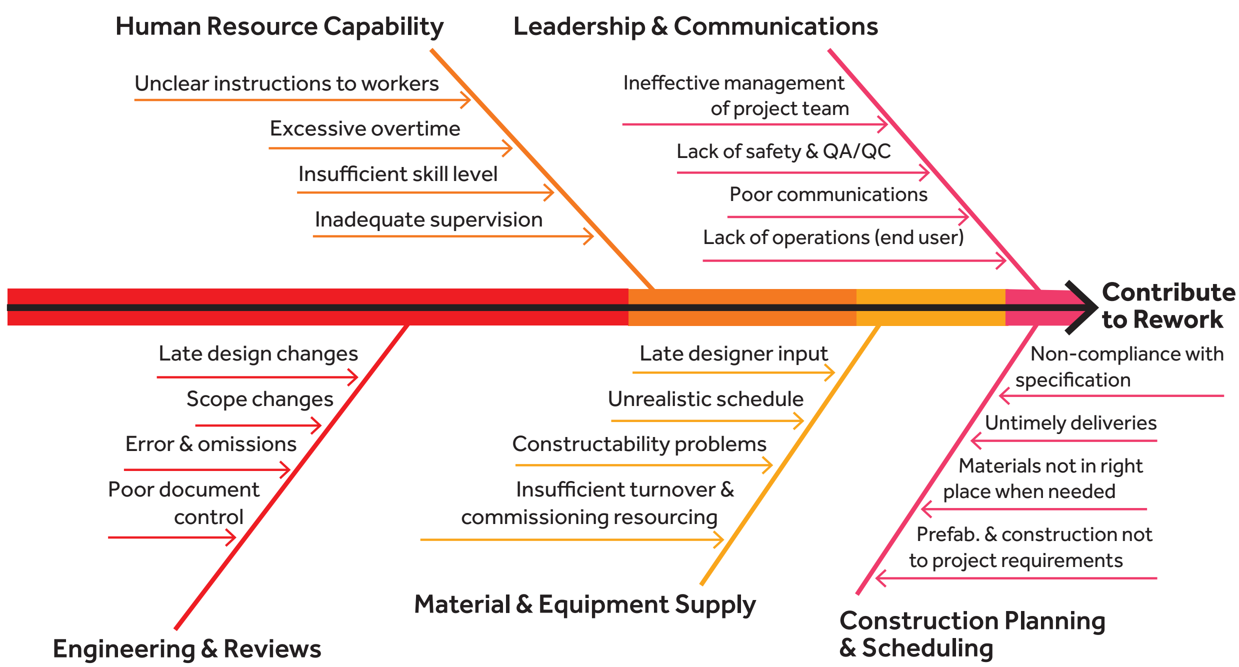
Section 3
Cost and Root Cause Overview

As early as 1981, the Building Research Establishment (BRE) in the UK referenced that rework can occur during different phases of the project life cycle and that errors in building had 50% of their origin in the design stage and 40% in the construction stage. In 1986, O’Conner and Tucker’s Industrial Project Constructability Improvement paper identified owner scope change, specification change in addition to design or procurement errors that result from poor construction technique or poor construction management processes. Abdul-Rahman (1995) determined non-conformance costs in a highway project to be 5% of the contract value (excluding material wastage and head office overhead). Abdul-Rahman specifically points out that non-conformance costs may be significantly higher where poor quality management practices were implemented. Nylen K.O. (1996) found that when poor quality management practices were used in railway projects the quality failures were found to be 10% of the contract value. Furthermore, 10% of the quality failures represented 90% of their total cost. Additional studies indicated that rework has a considerable impact on the industry as a whole; sources of these studies included the American Society of Civil Engineers (ASCE), Burati J.L et al (1992), CII (2004), Peter E. D. Love (2002, 2008 & 2010) and a recent white paper produced by Navigant Construction Forum (2012). This research is further supported by other survey data that suggest that the total mean rework can be as much as 10% of the contract value. Research conducted by the ASCE and CII finds that direct cost of rework contributes an average of 5% to the total construction cost (CII, 2005), however where head office overhead and indirect costs are taken into account, the percentage of rework contributing to total construction costs can exceed 7.25% and reach as high as 12%.

Figure 1.0 illustrates the five main sources of rework and their associated root causes (Fayek et al. 2003). Of those identified in Figure 1.0, “Engineering and Reviews” had the highest monetary weight at approximately 60%, according to one survey, far and above any other source identified in the figure. The second highest source was “Human Resource Capability” at 21% and third highest was “Material and Equipment Supply” at 15%, although the frequency of occurrence was far greater than the Human Resource weighting. “Construction Planning and Scheduling” and “Leadership and Communications” had almost identical weighting.

Fig 1.0 Cause and Effect Diagram - Model of the Root Causes of Rework *(Fayek et al. 2003)*



Section 4

Productivity Loss and Reduced Quality in Projects

Failure to deliver project needs on time and on budget has been the downfall of political parties, governments and public entities around the world. Where delays in projects occur, the Project Manager is usually forced to consider three possible situations: decline in quality, additional costs and possible rework. A decline in quality will usually lead to rework, while introducing additional resources to meet project schedule constraints significantly increases project costs. Likewise, loss of productivity may occur due to longer periods of overtime if project acceleration is required to resolve delays. Where this approach is adopted, fatigue will invariably increase leading to sub-standard performance that may also generate rework. If extra resources are implemented, the outcome may lead to labor overcrowding and stacking of subcontract trades, which also has a potential to reduce work effectiveness, which in turn can lead to non-conformance.

While productivity loss and the choice of overtime work are important and interesting factors, it is not the purpose of this paper to study the relationship between overtime work and productivity. This whitepaper concentrates on the effect of rework quality on the cost and schedule function.

Key selection of resources that best reduce productivity loss and best resolves delays is carefully scaled by injecting 50% overtime work and 30% additional resource.

Allocation of resource is further explained in Section 5.

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Section 5
Examination of Design-Induced Rework

Rework resulting from client design changes or design consultant error has been identified as the primary factor contributing to time and cost overruns. Design-induced rework has been reported to contribute as much as 70% of the total amount of rework experienced in construction and engineering projects (Peter E. D. Love et al 2008). In spite of lessons learned from project failures and design errors, poor design and construction management practices continue to plague the construction industry. Errors made during the early stages of a project are often detected during the later stages of the project, after what appears to be an "error free - undetected period." Design errors from architectural and engineering professionals that go undetected may lead to Structural, Geotechnical and Civil Engineering or Mechanical failures that can have catastrophic consequences, as the following examples illustrate:

- Tay Bridge, 1879 – central navigation spans collapsed into the Firth of Tay at Dundee, taking with it the train and six carriages and 75 people
- Teton Dam, 1976 – collapse of the Earth Dam in Idaho. Geotechnical and design decisions led to failure without building multiple layers of redundancy and defense against failure
- London Millennium footbridge, 2000 – synchronous lateral excitation causing sideway sway motion similar to Tacoma Narrows Bridge that collapsed in 1940
- Paris Charles De Gaulle Airport, Terminal 2E, 2004 – six modules of the tubular structure, in addition to three footbridges which linked the boarding area collapsed

The prime reason for these issues is due mainly to industry timeline expectations, pressures and client demands. Design consultants are generally too quick to move on to the next bid or are preparing the next phase of the project to fully understand and reflect on these past design issues, design defects and the review of their processes. The procurement process for public bidding, in particular, can increase the likelihood of rework. The handoff of incomplete design related documentation, which is then relied upon by contractors or design-build teams to compile tender documentation and budgets can create reliability problems as these errors in documentation are not detected until operations begin on site. In some cases this may directly affect the engineering and plant operation, which will then impact safety.

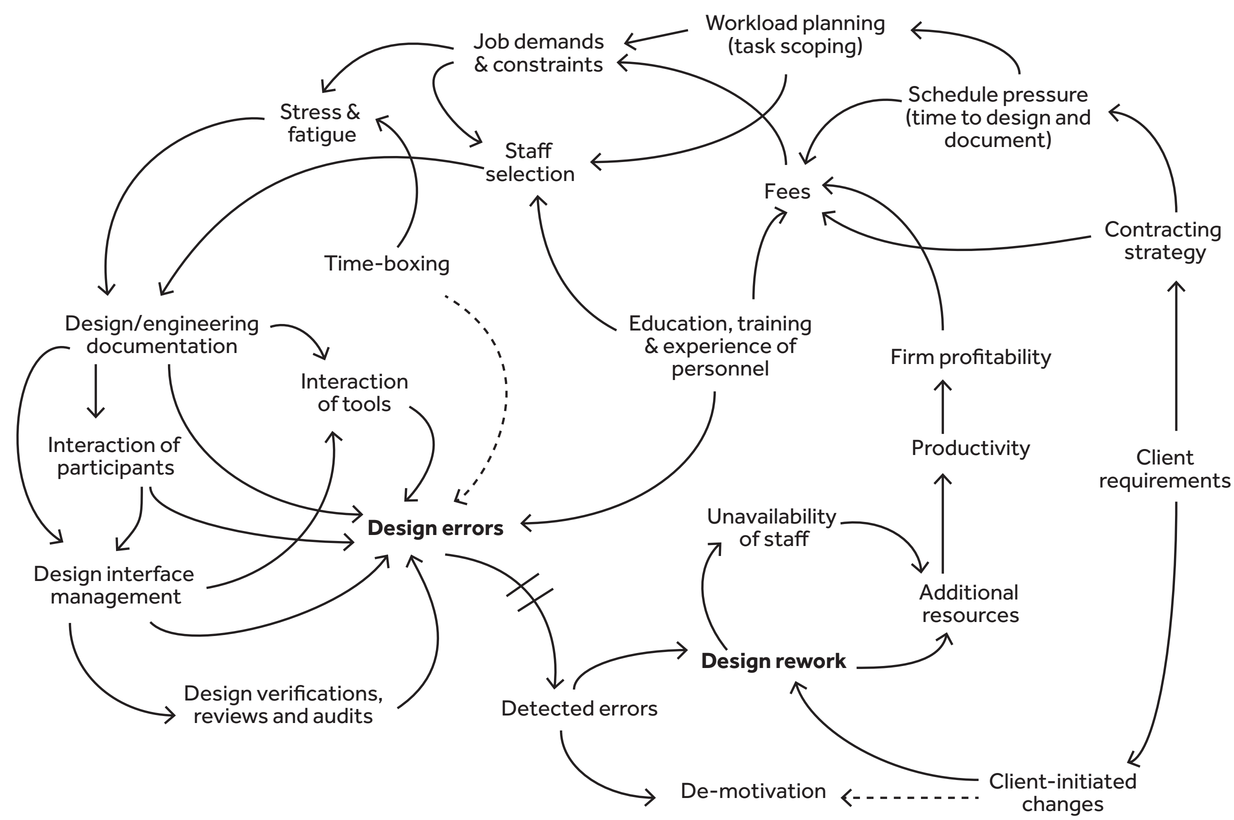
If we drill down into the design error causes we can see more elements that drive consultants to make errors, which affect their performance and further influence their decision-making process.

Management decision-making and other soft variables have had limited empirical research and have not been systematically studied or presented and referenced here. Conversely, the review of Management and Organizations, and how these affect human behavior, is well documented. The types of errors that stem from these types of characteristics are usually defined as those arising from (i) poor knowledge, (ii) carelessness and negligence and (iii) intent (due to greed etc.). If we concentrate on (i) and (ii) above, we find that poor knowledge is a result of poor training and education combined with a lack of experience. Carelessness and negligence often include errors in detailing and calculations and are mostly due to a lack of due diligence and therefore may be made at any time during the project's life cycle, as addressed earlier.

Fig 2.0 (on page 4) represents an influence diagram that identifies key issues from studies in the design phase (from conceptual through detailed design stages) that can affect a designer's cognitive reasoning, and therefore the likelihood to commit errors. Other causes are ineffective use of computer aided design, low design task awareness, lack of teamwork and lack of awareness in changes in design standards. As previously stated above, work pressures due to schedule constraints are also a key indicator. "Design change induced rework is generally client initiated and invariably results in modification to the contract". (Peter E. D. Love 2008) The resulting cost and schedule impact are usually mutually agreed upon by the client and contractor. Love and Li (2000) also found that changes during construction were initiated by the end user; client based change accounted for up to 25% of rework costs. An alternative explanation as to what leads to design error can be categorized as those client requirements that have not been fully understood, especially where there is indirect communication between designer and end user of the facility. This type of communication can create more difficulty in the relaying of information and create a misunderstanding for designer and, thus, the tasks.

Schedule pressure and unrealistic client demand for earlier completion of projects have been reported to be contributors to the working of incomplete and erroneous project contract documentation. Schedule constraints and client pressure often lead to lack of attention by management resulting in poor quality and requiring rework that can ultimately affect profitability and project performance. This is especially true when a low design fee for a project is submitted and a fixed duration allocated for each design task. This could lead to inadequate time to prepare documents and may be more profound if inexperienced design staff with limited technical knowledge is involved, as this could amplify the incompleteness of these documents.

Figure 2.0 Influence Diagram Of Design Error Induced Rework *(Peter E. D. Love 2008)*



Cognitive behavior and time pressures also have an impact. A designer's knowledge is generally limited to his or her own activities, which can contribute to that designer's inability to detect errors. When subjected to time pressures, people will tend to maintain their routine behavior even when they have been informed of an alternative way of assessing a problem, which can produce negative results. The same can be true of rectifying errors. If consultants or contractors are checking for design errors they can invariably make the same mistakes. Where the process becomes compounded is when multiple disciplines such as architectural, mechanical and structural engineering and geotechnical engineering are subjected to degree of concurrency, also known as parallelism. In the 1999 article "Limits of Concurrency", G.M. Hoedemaker notes there is a limit to the number of tasks that can be undertaken in a concurrent manner and the probability of rework and cost and schedule overruns significantly increases and becomes exacerbated when the team is under timeline demands due to schedule slippages. Low salaries can also act as de-motivators, which in turn can contribute to errors in design. If a firm submits a low design fee for a project, it may put higher pressure on designers to meet schedule. The occurrence of rework will invariably result in contractors reevaluating their project schedules, as delays have the potential to lead to Liquidated Damages.

As noted in the Causal Behavior of Design-Induced Rework published by IEEE (2008) and written by Peter E.D. Love, there can be vast changes in the original scope due to design errors and even though projects may be delivered on time, significant cost overruns can still occur. Peter E.D. Love's paper identifies that the total percentage of cost rework attributing to cost overruns were in excess of 40%. This is comparable to the research completed by Love in 2002, which stated that on average rework contributed to 52% of the projects' total cost overrun. This comparison is discussed in more detail in Section 6.

Powell (1997) suggests that insularity and architectural firms' poor management practices and aversion to management, in general, are other factors. Indeed, architectural firms have been identified as the primary source of design-related rework in projects. With the exception of ISO 9000, quality controls like total quality management (TQM), quality costing, quality improvement teams and quality function deployment were rarely

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employed. Architects should commit to and strive to follow a structured TQM program; doing so will help eliminate unnecessary and avoidable revisions.

Undertaking design reviews and selecting staff with commensurate skill level and experience to manage the design process is the first stage to ensuring potential design errors are minimized. A firm that supports inter-organizational collaboration with the use of Building Information Modeling (BIM)/Project Information Modeling (PIM) and clash detection and one that examines its work practices (such as those developed by CII) will do well in reducing rework. What is difficult to minimize or control is if the designer is responsible for the error. Unless it is a simple problem, the design firm may need to regroup the designers responsible. These designers may already be working on different projects, groups or teams; in a worst case scenario, they may have left the firm. In any event, the process of recruiting or inducting designers may well have to start all over again and delay the project or force a hasty decision, any combination of which may cause non-conformance.

Section 6

The Effect of Rework on Construction Cost Performance

The CII Capital Program benchmarking and metrics program collected data for approximately 360 projects where direct rework costs were measured as a portion of actual construction costs. CII developed a formula to calculate a metric known as Total Field Rework Factor (TFRF), which is expressed as Total Direct Cost of Field Rework over the Total Construction Phase Cost as a leading indicator used for this group data analysis. The data samples were split into two groups, one for Owners and one for Contractors, with the results being analyzed separately for each group.

Formula for Total Field Rework Factor:

$$\text{TFRF} = \frac{\text{Total direct cost of field rework}}{\text{Total construction phase cost}}$$

Two statistical hypotheses were established for this study: (1) the significant differences in the impacts of rework on construction cost performance for various project groups, which are identified throughout this section and (2) the statistically significant difference in rank order of rework sources. For hypothesis (1), a rank-order correlation was tested using a one-way ANOVA, which is a commonly used method to calculate the difference in means between two groups; this test has a confidence level of 95%.
For hypothesis (2), the rank of scores (not the scores themselves) were rank ordered using the Spearman correlation test, which concentrates on differences in rank order of data rather than their mean differences.
Sources of rework that were classified in the study are as follows:

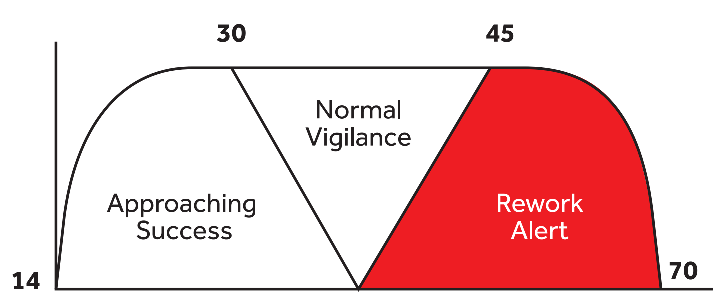
- Owner Change (OC)
- Constructor Error (CE)
- Design Error/Omission (DE)
- Design Change (DC)
- Vendor Error/Omission (VE)
- Vendor Change (VC)
- Constructor Change (CC)
- Transportation Error (TE)
- Other (OS)

Table 1.0 Rework Questionnaire Index					
	Questionnaire	Answer (option)	Score	Answer (option)	Selected Score
1	Degree of alignment between various elements of the owners organization (departments, divisions)	Could not be better	1 2 3 4 5	Could be worse	
2	Degree to which project execution planning was utilized	Completely	1 2 3 4 5	Not at all	
3	Design firm's qualifications for the specific project	Could not be better	1 2 3 4 5	Could not be worse	
4	Degree to which leaders of key design disciplines have changed	No change at all	1 2 3 4 5	Continual change	
5	Quality of field verification of existing conditions by engineering	Could not be better	1 2 3 4 5	Could not be worse	
6	Quality of interdisciplinary design coordination	Could not be better	1 2 3 4 5	Could not be worse	
7	Quality of prequalification of vendors for the project	Could not be better	1 2 3 4 5	Could not be worse	
8	Availability of vendor information for equipment	Could not be more available	1 2 3 4 5	Could not be less available	
9	Degree to which design schedule is compressed	Not compressed at all	1 2 3 4 5	Could not be more compressed	
10	Level of overtime worked by the engineering firm	None	1 2 3 4 5	Very high level	
11	Level of design rework (repeating design work)	Could not be lower	1 2 3 4 5	Could not be higher	
12	Commitment to constructability of the design and construction team	Total Commitment	1 2 3 4 5	Total lack of commitment	
13	Expected availability of skilled craft workers to the project	Readily available	1 2 3 4 5	Very scarce	
14	Expected level of construction contractor overtime	None	1 2 3 4 5	Very high level	

The TFRF formula can be used with each of the nine sources of rework to identify the highest impact on cost performance. CII's research team also developed a field rework question-naire index to help identify the need for rework early on in projects, which serves as a performance indicator with the objective of reducing rework and ensuring the intended purpose could be completed before the start of construction.

CII's questionnaire Field Rework Index (FRI) and rework chart are found in Table 2.0 and Fig. 3.0. All answers with a rating of 1 receive 1 point; all ratings with a rating of 2 receive 2 points, and so on through to a maximum of 5 points. The score for each question is then added together to give a total score; those with a score between 14 and 70 are grouped according to the FRI score categorizing chart. Those scoring higher than 45 are classified as being within a Rework Alert stage.

Fig 3.0 FRI Score Chart



OWNER-REPORTED PROJECTS

The owner-reported project results revealed that the mean TFRF for **light industrial** was the highest and that heavy industrial was lowest. Therefore the cost of impact of rework in light industrial projects is significantly greater than that of **buildings** or **heavy industrial** sources. Rework in modernization projects contributed to the increase of actual construction phase costs, almost twice as much as add-on projects.

The results based on Project Size found that the mean TFRF for projects between $50M and $100M were the highest, but as Hwang et al (2009) points out, this is based on a small sample, and has less statistical significance. The lowest mean TFRF was recorded for projects of less than $15M, but again these findings lack real significance based on their sample size. Projects costing greater than $100M identified that Design Error contributed the most. Project location did not reveal any significant trends in mean TFRF differences to constitute real rework impacts.

Mean TFRF values per industry group per source of rework were also described. The results suggest that Design Error (DE) and Owner Change (OC) in **buildings** were higher than those of any other sources in that group. From this sample of analysis we can predict that DE and OC contribute more to construction phase costs than any other source for buildings. In the case for **heavy industrial** the mean TFRF for DE was higher than any other source by large margin.

For light industrial, DE and OC were ranked quite closely as the most common source of rework.

Overall, for each category, Design Error was the highest in all Industry groups except Infrastructure and Modernization. The Hwang et al study suggests that $0.018M per $1M actual construction costs contributed to Design Error.

In all groups categorized by Project Nature, the mean TFRF for DE and OC were higher than those for other sources including Design Change, Vendor Change and Transportation Error.

CONTRACTOR REPORTED PROJECTS

Design error had the greatest impact on heavy industrial projects, but the true cause of impact to rework on infrastructure projects was not clearly defined (source was categorized as Other). In all groups categorized by Project Nature, category DE and OC were ranked first and second highest by cost impact. In fact, DE, OC and DC for add-on, grass roots and modernization projects were significantly different to those of CC, VC and TE.

Table 2.0 Largest Sources of Rework for Owners and Contractors *(Bon-Gang Hwang et al, March 2009)*

Project Characteristics		Owner			Contractor		
		First	Second	Third	First	Second	Third
Industry Group	Buildings	DE	OC	OS	CE	CE	VE
	Heavy Industrial	DE	OS	OC	DE	OC	VE
	Infrastructure	OC	CE	DE	OS	DC	DE
	Light Industrial	DE	OC	OS	DC	OC	DE
Project Nature	Add-on	DE	OC	OS	DE	OC	DC
	Grass Roots	DE	OC	CC	DE	OC	DC
	Modernization	OC	DE	OS	DE	OC	DC
Project Size	<USD15 Million	OC	DE	OS	DE	OC	DC
	USD15-50 Million	DE	OC	OS	DE	VE	OC
	USD 50 - 100 Million	OC	DE	OS	OC	DE	CE
	>USD100 Million	DE	CE	VE	DE	VE	OC
Project Location	Domestic	DE	OC	OS	DE	OC	DC
	International	DE	OC	CE	DC	DE	OS
Work Type*	Construct Only	--	--	--	DE	DC	OC
	Design and Construct	--	--	--	DE	OC	VE

KEY: OC = owner change; DE= design error/omission; DC = design change; VE = vendor error/omission; VC = vendor change; CE = constructor error/omission; CC = constructor change; TE = transportation error; OS = other
* Contractor-reported projects only

In terms of ranking by Project Size, DE had the highest mean TFRF and all ranking correlations were significant, except where project costs were between $50M and $100M, and in this case DE and OC shared the same TFRF. Table 2.0 (on previous page) summarizes the largest sources of rework for both owner and contractors.

Section 7

Rework Costs in Building Construction.

According to Peter E.D. Love (2002) cost growth for 161 Australian construction projects surveyed found that Rework as a Percentage of the Total Cost Growth could be up to 52%, and factors such as weather, client/end-user change orders contributed to the remaining 48%. A surprising finding of the project data revealed that 27% of projects were delivered on time despite experiencing cost increases due to rework. As stated in section 4 above, projects can be accelerated and resources allocated to compensate for any delays, which will inevatably increase project costs.

Key Predictors:

- Changes made at the request of the client or occupier when a product or process has been completed
- Value management and its use to reduce rework
- Ineffective use of information technology
- Design scope freezing

While looking into rework costs and procurement methods, there were no significant differences between the Procurement Method category for direct and indirect rework costs. In this survey it was also noted that there was no significant difference between the total cost of rework using different procurement methods and the result of the one-way ANOVA test.

Refurbishment and renovation projects are considered higher rework costs than those for new building projects. Using the one-way ANOVA test there were no significant differences between Project Type and direct and indirect rework costs. Table 3.0 below looks at the Project Type vs. direct and indirect costs; the mean value for each does not draw significant differences by project type. It is thought that the higher the uncertainty and complexity of work the higher the rework cost, but again this is not necessarily supported by the results of this survey. This is, however, backed up by several reports and findings of root causes of rework.

Lastly, the allocation of resources and planning during the documentation process are important points that need to be raised if rework is to be reduced. Noteworthy is that design consultants rework estimates are almost twice as much as PM's, where as contractors have a better understanding of actual rework costs, because they are integrated within the consultants' design and construction activities, especially where design-build projects are concerned.

Table 3.0 Direct And Indirect Rework Costs Per Project Type, *(Peter E.D. Love 2002)*

		Direct Rework Costs					Indirect Rework Costs				
Project Type	*N*	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Mean	Standard Deviation	Standard Error	Minimum	Maximum
New build	90	6.10	7.18	0.75	0.10	35.00	5.69	7.70	0.81	0.00	50.00
Refurbishment/ Renovation	43	7.29	9.73	1.48	0.50	50.00	5.60	6.43	0.98	0.00	30.00
Fit-out	14	7.78	7.70	2.06	1.00	30.00	6.10	7.90	2.11	0.00	30.00
New build/refurbish	11	4.95	4.67	1.41	0.50	15.00	5.81	5.92	1.78	0.00	20.00
Combination of all	3	3.33	1.52	0.88	2.00	5.00	0.66	0.57	0.33	0.00	1.00
TOTAL	**161**	**6.44**	**7.78**	**0.61**	**0.10**	**50.00**	**5.62**	**7.18**	**0.56**	**0.00**	**50.00**

Section 8
Rework Costs in Civil Infrastructure Projects

Peter E.D. Love et al (2010) noted that from 115 civil infrastructure projects surveyed, mean rework costs were lower than the previously reported mean rework costs for building construction projects. The results that influence direct rework costs on cost growth for civil infrastructure projects were also considerably less than in building construction: 12% compared to 26% respectively, more than half of what was reported in building construction.

Key Predictors:
- Ineffective use of information technologies
- Working procedures and communications lines not clearly defined
- Excessive client involvement in the project
- Changes made at the request of the client
- Insufficient changes initiated by the client contractor to improve quality

Again, while looking into rework costs and procurement methods, it can be concluded that there were no significant variances among procurement method categories for direct and indirect rework costs, nor were there any significant differences revealed for the project type (railway infrastructure was not included among the project types sampled).

It was noted also that there is a difference of underlying predictors of rework between building construction and infrastructure projects, though inefficient use of information technologies by design team members is common to both. As noted by Love (2009) when projects are subject to tight design schedules, design team members often reuse standard details and specifications to minimize their task loading. Together with interoperability issues and information technology applications, this can lead to tentative design information.

Section 9
Conclusion

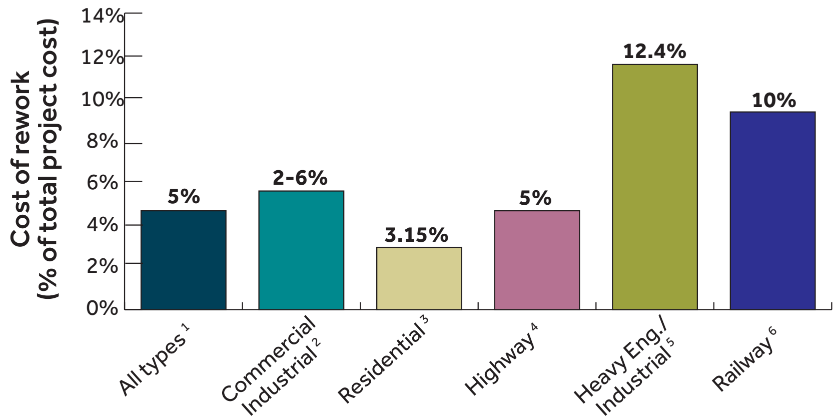
For owner-reported projects, heavy industrial work had the lowest reported TFRF. Conversely, heavy industrial projects were the most affected among contractors. Circumstances where the TFRF results did match between owner and contractor were due to the effect of rework cost increases for modernization and projects for which the cost range was between $50M and $100M. Surprisingly, the trend showed that rework did not greatly influence cost increases where project values are greater than $100M, although the sample size was not significant. There are two main assumptions that may suggest why rework is not so disruptive with project values greater than $100M. These are either due to the successful execution of best practices, such as CII Performance Improvement and Assesment, and the use of BIM, or it could mean that these projects may be less sensitive from a cost standpoint and perhaps the validity may be in question.

There is not enough thorough rework research data to suggest that BIM diminishes potential rework, but the process of preparing the BIM workflow and modeling in a collaborative effort does decrease opportunities for rework.

What is clear from studies is that the cost of rework for owners is twice as high as for contractors, although the owner is generally in control of the whole project as opposed to a section of the project given to a contractor. Consequently the owner bears a significantly larger proportion of financial responsibility. The most susceptible projects affected by rework are light industrial, heavy industrial, railway projects and modernization projects and projects for which cost range is between $50M and $100M. See figure 4.0 which summarizes these most sensitive project types.

For owners, OC and DE were most frequently ranked amongst all categories. CE was also found on owners categories such as projects costing more than $100M and infrastructure projects.
For contractors, OC, DE, DC and VE were most frequently ranked as the most prevalent sources of rework. DC was one of the higher cost of rework categories for the contractor but was less so for owners. CE was highly ranked on the owners side but less so for contractors rework impact data. There is an ongoing trend for contractors to assign rework to design error and omission; the owners attribute the cost of rework to constructor error and omission.

Fig 4.0 A Summary Of Rework Costs *(Bon-Gang Hwang)*



1 CII (2005)
2 Josephson and Hammarlund (1999)
3 Love and Li (2000)
4 Abdul-Rahman (1995)
5 Burati et al. (1992)
6 Nylen (1996)

It can be said that although the cost impact of rework is different among groups, the greatest cost impact sources in groups were highly correlated, for example **DE** and **OC** are the two most frequently ranked sources by cost impact and can be considered to be the most important root cause for both contractor and owner. It can also be noted that CE for owner reported projects and DC for contractor reported projects are also great contributors to rework. Ineffective use of IT by design team members was the primary factor contributing to DE.

To reduce rework, firms should implement quality operations such as pre-project planning, benchmarking processes, project change management and constructability and design effectiveness. Furthermore, firms should improve management of design and documentation processes and communication among owner, designers and constructors to create a guiding coalition, and a shared objective and mutual trust. Overall change requires leadership and management; the larger the change the more leadership is required. Project Managers should analyze, think ahead and change by taking the lead to develop and implement systems for tracking and controlling constructor error and omission for owners, design change for contractors, owner change, and design error for both contractors and owners to try to reduce rework by these sources. The underlying message is to remove complacency and address past failures and learn from them by implementing CII best practices, while improving learning capabilities and stimulating organizational learning.

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Risk Engineering Consultant
Robin McDonald is the Lead Risk Engineering Consultant for XL Catlin's Construction Professional Liability practice. Previously he served as a Construction Manager with Parsons Corporation, leading Risk and Cost Management for the WTC Redevelopment Program.

With a broad range of engineering consulting experience spanning four countries and sixteen years, Robin has had exposure to business development, design, pre-construction analysis and project management on "Mega" Building and Infrastructure Projects. His background in construction and engineering is diverse, derived from years of experience with reputable firms which began in the UK and continued overseas; including Channel Tunnel Rail Link (UK), the New Jersey Nets Sports Arena (NY), 12-Month management of a multi disciplined Site Satellite Office in West Indies, Jamaica, Haiti and recently with the World Trade Center Redevelopment Program (NYC). Robin also has Earthquake Rapid Response experience in search and recovery, which includes management of operational support, forensic demolition and site oversight, and quality control.

Robin is a Certified Construction Manager (CCM) and Member of the Construction Management Association of America (CMAA) and is a LEED Accredited Professional. He is a recent graduate of the Cleantech Executive Program at NYU-Poly, which is affiliated with the New York City Clean and Renewable Economy (NYC ACRE) program that focuses on environmental sustainability and smart technology growth. He received a B.Eng (Hons) in Civil, Structural and Environmental Engineering from University College London (UCL) in the UK and also holds a Post Graduate Advanced Engineering Management Degree at Bath and Bristol University (UK).

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