STUDY ON FACTORS AFFECTING REWORK IN BUILDING CONSTRUCTION

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IN

CONSTRUCTION PROJECT MANAGEMENT

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this dissertation, and material thereof is, in part or whole, not previously submitted for a degree or diploma in any university to the best of my knowledge and does not contain previously published or written by another person except where due references are indicated.

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ABSTRACT

Rework which is often experienced in construction projects is primarily caused as a result of poor site management practices mainly contributed in presence of incompetent knowledge and supervision, poor workmanship, insufficient supervision, improper work protection.

Recent research has shown that rework is the significant cause for schedule and cost overruns, quality deviations, poor safety, and client and contractor dissatisfaction in the building construction industry. Reducing rework is widely regarded as an effective way of improving construction performance in terms of productivity, cost, schedule, quality and safety.

The research presented in this paper uses multiple completed building projects to identify the significant variables that contributed to rework. Rework factors' identification and categorization are carried out on the basis of rework performing groups in the design and construction process and best practices are proposed in considering the stages of design and construction.

This research develops generalized best practices and checklists, which are intended to reduce rework by managing construction building projects for the purpose of performance and productivity improvement. Also, they can enable project managers to better understand priority areas in the process of site management practices in construction projects.

Keywords: Building Constructions, Rework, Causes, Best Practices.

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Abbreviations

BP	-	Best Practices
COAA	-	Construction Owners Association of Alberta
CIDA	-	Construction Industry Development Agency
CPD	-	Continuous Professional Development
PRRT	-	Project Rework Reduction Tool
QC	-	Quality Control
QA	-	Quality Assurance
RRP	-	Rework Reduction Program
RRM	-	Random Rubble Masonry
RCC	-	Reinforce Cement Concrete
TQM	-	Total Quality Management

1.0 Introduction

1.1 Background

Rework means a work executes more than once in order to achieve the specific objectives, objectives resulting the unnecessary usage of additional resources in the form of labour, materials, machines hours and other facilities beyond what it would have been used if the work had been performed only once.

It is a regularly foundfeature of construction process and is a primary factor that contributes to time and schedule overruns, cost overruns, quality deviations, and poor safety typically plagued projects in the building construction industry. These challenges affect the delivery of projects within the specified deadlines and estimated budget. Building projects involve multiple consultants, contractors, suppliers and trades that interact with one another, and also can affect progress in areasof constructions. In such a complex environment, many activities take place simultaneously − errors, omissions and misunderstandings − often causing undesirable outcomes that must be reworked.

Poor quality managed project can result in reworks and it leads to extra cost and time extensions. It is therefore vital for project managers to understand the client's requirementsin terms of cost, quality, and time. Management has to be aware of customer requirements and be responsible for creating the right environment for a progressive improvement. Also, it has to produce realistic estimates to match these requirements.

The construction industry lacks exposure to the tools and methods which have been applied successfully in the manufacturing related items to promote the quality of products.

Also, theother primary sources of rework in construction are effects of the documentation on which the construction activities are based. These largely consist of design changes, errors and omissions. Thus, in order to understand the origins and casual nature of rework, it is necessary to model the design process to determine why and how rework originates so that it can be prevented through integrating design management with comprehensive project management.

By gaining awareness of the mechanisms causing rework, its reduction can be made in the implementation. Previous studies have not been able to generalize the key factors that contribute to rework. The research presented in this paper, however, uses multiple completed projects to identify the significant variables that contributed to rework. These variables are used to develop best practices and methodologies that could be used to reduce rework in construction projects.

In addition, there are numerous government initiated reports which have criticized the industry for its fragmented nature, lack of coordination and communication among parties, adversarial contractual relationship, and lack of customer-supplier focus, price-based selection, and ineffective use of technology. Such poor organizational and management practices have contributed to time wastage, unnecessary costs, increased errors, and misunderstandings, which have invariably resulted in rework occurring in projects.

It is neither realistic nor fair to consider field rework as caused by construction site activities alone, as more often causes are far deeper rooted beyond the responsibility of contractor. Therefore, it is necessary to address all principal rework causes,whereverthey may originate. Client design changes are also frequent, generating costly ripple effects that create delay, rework and disruption throughout the entire projects. Projects often appear to be going smoothly until near the end, when rework causing deficiencies are discovered as early as possible only.

With the implementation ofthebest practices and checklists and early recognition of deficiencies pertaining to rework, it will dramaticallyimprove the project performance and productivity by avoiding expensiveand frustrating fieldrework.

1.2 Problem Statement

The construction industry boom in Sri Lanka is currently undergoing rapid growth, particularly in the building construction sector. Several mega-projects are underway at present. So, schedule squeeze to speedy construction is always huge challenge because it leads to rework and cost overruns. And in the involvement of multiple parties for the design and construction process, occurrences of rework are often difficult to avoid. Then, the resulting rework will have the potential to negatively affect the project time and cost as well as the satisfaction of both contractor and client.

Research in this area, is important because the problem of defects and rework during the construction period become inherent feature even in the same work categories as well as in the same projects. In the building construction sector, quality of construction is utmost important because such products have high demand in the market. In achieving a standard methodology for tracking and classifying rework in the construction industry, a comprehensive solution can be found and application of best practices can be implemented simultaneously. House builders will alsofocus on the quality of the product they offer in order to attract buyers.

Despite the fact numerous studies have been conducted on rework, there is no effective methodology found to reduce and prevent rework as it occurs in the field. Currently, even in Sri Lanka context, there is no effort to track and minimize rework, making it difficult to assess the amount of rework on an industry-wide level.

1.3 Research Objectives

The overall objective of this research is the improvement of construction performances and productivity inLanka'sbuildingconstruction industry by focusing on reducing rework with the implementation of best practices as the rework is one of the major determinants of construction performance affected.

The specific objectives of the study are:

- To identify factors affecting rework in building construction
- To propose best practices to minimize rework in building construction
- To develop checklists to minimize rework for selected trades

1.4 Significance of the Research

Rework occurrences adversely impact the project performance aspects with respect to costs, time, and stakeholder satisfaction. The project management, as a result of the direct impact of rework, is suffered with the excessive use of time, materials, labour, and related materials handling wastage and extension of labour and supervision of manpower.

This study is significant in several aspects including:

1. It addresses rework as a major determinant of construction performance and productivity.
2. It increases awareness of the possible problems which may result from rework.
3. Enhancing the productivity levels by reducing rework which in turn will positively impact the progress of the project and consequently the project performance.
4. Reducing cost overrun associated with rework.
5. Reducing time overrun associated with rework.
6. Raising the morale of employees of different project participants which result from doing perfect work first time.
7. Reducing or minimizing any possible conflicts which may result because of rework.
8. Considering any possible rework causes in the preplanning phase of the project.

Rework is a significant contributor to time wastage and time/schedule overruns which will eventually impact on costs, resources, and quality as well.

Rework also triggers claims for extra costs and time wasted in redoing or repairing, given that contractors for example, would seek some form of compensation from whom they consider responsible, wherever possible.

In addition to the direct impacts (time, cost, resources) on specific activities/tasks, the rework occurrences will often have some indirect impacts (on several other related activities/tasks) Thus, in poorly managed projects, the gross impacts of rework could be exceeded the anticipated markup/profit margin levels. From many reported cases, it could be affirmed that rework have negative impact on the performance of projects in terms of cost overrun, time overrun and dissatisfaction of the participants on the project. Impacts are enormous on project; Palaneeswaran (2006) argued that the direct impact of rework on project where it was identified consists of additional time to carry out the rework, additional cost to rectify the occurrence, more materials for rework and wastage, and consequential increase in labour cost to fix the defect plus related extensions of manpower supervision. Hence, if rework is to be reduced or avoided, there is a need for clients' initiating a construction activity to reduce changes or alterations to design after the commencement of work.

1.5 Methodology

For the purpose of research presented in this paper to achieve the objectives, rework is defined as "the unnecessary effort of redoing a process or activity that was incorrectly implemented at the first time". An interview is proposed to collect data as it gives respondents specific information rather than general opinion. Questions for the interview to achieve research objectives are listed and those are taken up to respondents at the time of interview to examine the influence of project management due to influences on rework occurrences in projects.

Respondents are asked to select recently completed projects most familiar to them and to answer questions about the perceived causes of rework mostly occurring in rework trades. Also, proposed best practices to minimize rework in project management practices are recorded. In essence, each project identified by respondents' is treated as a separate case.

1.6 Results

One of the most significant contributions arising from this study is the analysis and treatment of field rework issue. In attempting to address this issue, this research is conducted to identify factors affecting rework on the recently completed building projects.

Conducted classification system for the purpose of identifying root causes of rework, site management factor is contributed significantly to occurrences of rework in the building construction sector over the design and engineering factor and client factor. In further analysis of site management factor, knowledge and supervision contributes to rework with 53.75% while poor workmanship and insufficient management and supervisory skills contributes to same 17.5% and 15.95% respectively. Apparently, an increased emphasis in respect of root causes of site management factors is required to avoid and improve project performances. There are some conclusions disclosed from the study regarding severity of rework on work categories such as setting out, brick work, plastering concrete, and tile work.

Design and engineering is other main factor which is contributed to rework occurrence to 17%.Changes in design occurred mainly due to initial design is not done to site conditions, client's awareness lacks about especial features and scope of the work, errors and omissions in the drawings and specifications. As far as these root causes are concerned, all could be averted and minimized through having the closest link among stakeholders and effective communication.

And best practices are proposed to minimize rework in the building construction along with checklists for selected trades.

2.0 Literature Review

2.1 Introduction

Lack of adequate planning, scheduling, materials management, quality control and quality assurance are chronic problems of the construction. The effects of these problems include low productivity, poor safety, inferior working conditions, and inadequate quality in the construction projects. These rework have become an endemic feature of the construction process.

Earlier research has also provided anecdotal evidence of the root causes of rework especially the areas of project characteristics, organizational management practices and project management practices which influenced rework occurrences, but limited work has sought to determine the extent of those determinants (Love et al., 1999).

The organizational and project management practices have contributed to time wasting, unnecessary costs, increased errors and misunderstandings, which have invariably resulted in rework occurrences in projects. (Abdul-Rahman, 1993; Josephson and Hammarlund, 1999; Love et al., 1999).Indeed, research reveals that rework is a significant factor that contributes to project time and cost overruns. Chan and Kumaraswamy, 1997; Love 2002) also revealed that rework typically adds 10 per cent to total project costs. These costs may, however, be substantially higher because they did not account for schedule delays, litigation costs and other intangible costs of poor quality.

Studying correlation between cost and schedule growth and rework have been determined (Love 2002) leading to the desire to reduce the amount of rework on individual projects. The Construction Owners Association of Alberta (COAA) has, therefore, established a goal of developing industry best practices for reducing and preventing construction field rework. Before rework can be reduced and prevented, it must be quantified and measured and its root causes identified.

One of the most perplexing issues facing organizations in the construction industry is inability to stand with quality. As a result, sub-standard products and services often emanate which inadvertently affect the rework. Typically, rework is caused by errors made during the design process. These errors appear downstream in the procurement process and therefore have a negative impact on a project's performance.

On measuring severity of rework impact on project performance, previous researchers have classified the causes of rework(Love and Li, 2000;Love and Edward, 2004; Love et al., 1999) which have typically been sorted into categories including human performance, instruction and communication, design and engineering, planning and scheduling and material management supply(Love et al., 1997;Love, 2002;Fayek et al., 2004).These research efforts reached deeper, classified the root causes of rework, and conducted quantitative analyses of the causes in order to inoculate project performance against latent rework-causing issues. Most rework reduction tools based on these types of analyses were developed as sets of checklists to review a project’s processes, techniques, resources preparation, and environment for deficiencies(Coles and Haggard, 2005;Love et al., 2003).They operate on the expectation that rework can be averted if there is early and honest recognition of deficiencies exist(East 2004). Underlying these tools is the assumption that if we, ‘‘do it right at the first time,’’ rework can mostly be eliminated. While it is hard to disagree, rework persists in the industry, so a diagnostic and continuous improvement based approaches should be useful as well.

By building on these efforts, a generalized rework classification system and best practices are vital importance. This should come as accepted efforts with the support of industry experts and integrated it into the general construction management system is an effective approach to control the rework.

2.2 Rework in Building Construction

Rework is a significant problem in construction projects, particularly in building constructions as a result of involving multiple professionals, contractors, suppliers, and trades. Because of such a complex environment inherent in building construction, there are many activities take place simultaneously. So, some activities have to be done again due to errors, omissions, non-conformance and misunderstanding. This has, therefore, been defined as the effort of redoing a process or activity that was incorrectly implemented at the right first time (Love, 2000).

Quality management principles and tools are not strongly embedded in conventional construction management practice. As a result, rework is accepted as an inevitable feature of the construction process. Rework increases the likelihood of project time and cost overruns, and ultimately leads to client dissatisfaction. Participants involved in the construction process do not realize the extent of rework that actually occurs. There is an increasing need to improve the quality of operations in the construction process so as to reduce the incidence of rework.

In some countries, rework costs was found ranging between 12% and 15% of the total project cost(Davis et al,1989; Neese and Ledbetter, 1991).According to Taneja (1994) in structural and interior works of projects, the cost of rework be from 4%-12%of the total budget. These costs comprise approximately 46% for error in execution, 30% for error in designing and the rest are for the poor quality material, misunderstanding of drawing and external factors.

To effectively reduce the cost of rework in building construction, it is necessary to have an understanding of its causes and the construction industry has to become adoptive and responsive to the forces of change, both technological and social.

2.3 Rework Definitions

There are various interpretations of rework in construction management literature in terms of quality deviations, non-conformance, defects, and failures. According to Love in 2002, he identified two main definitions of rework: one is "the process by which an item is made to conform to the original requirement by completion or correction" (Ashford was participated in 2002) and other is "doing something at least one extra time due to non-conformance to requirements" (Construction Industry Development Agency 1995).

Love et al. (2000) defined rework as "the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time".

Roggie et al.(2001) define 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".

The COAA defines rework as the "total direct cost of redoing work in the field regardless of initiating cause" and also states that field rework does not constitute change orders(for new work),off-site fabricator errors or off-site modular fabrication errors.

2.4 Field Rework Data Collection Methodology

There were several field rework tracking and data collection methodologies found during the literature review presented briefly in the following. COAA in 2003, with the participation of Aminah Robinson, Fayek, ManjulaDissanayake, and OswaldoCampero, developed a data tracking methods shown in Figure 2.1 and used in the pilot study to monitor field rework events. The field rework event tracking process starts when an incidence was identified in the field, which involved redoing something in the field.

Site personnel usually identified these incidences, are: Workforce, Foremen, Field Technical Personnel, Field Engineer, and Quality Control Personnel. Depending on the incidence, they report it to the respective authority such as Project Manager, Site Manager or Quality Control Engineer in order to obtain instructions. The instructions will mainly fall into two categories as indicated in the diagram either to redo the work or accept it as is. If the relevant authority decided to redo it, they will have to issue instructions on the processes and appointed a time for accomplishing the rework. Necessary resources are assigned accordingly, and the rework is then carried out.

Once the rework event is tracked as described in above and its information is collected into the “Field Rework Data Collection Form” as shown in the Figure 2.2 under the “Data Entry” and “Define Rate” by observing the event, time sheets, and interviewing relevant construction personnel.

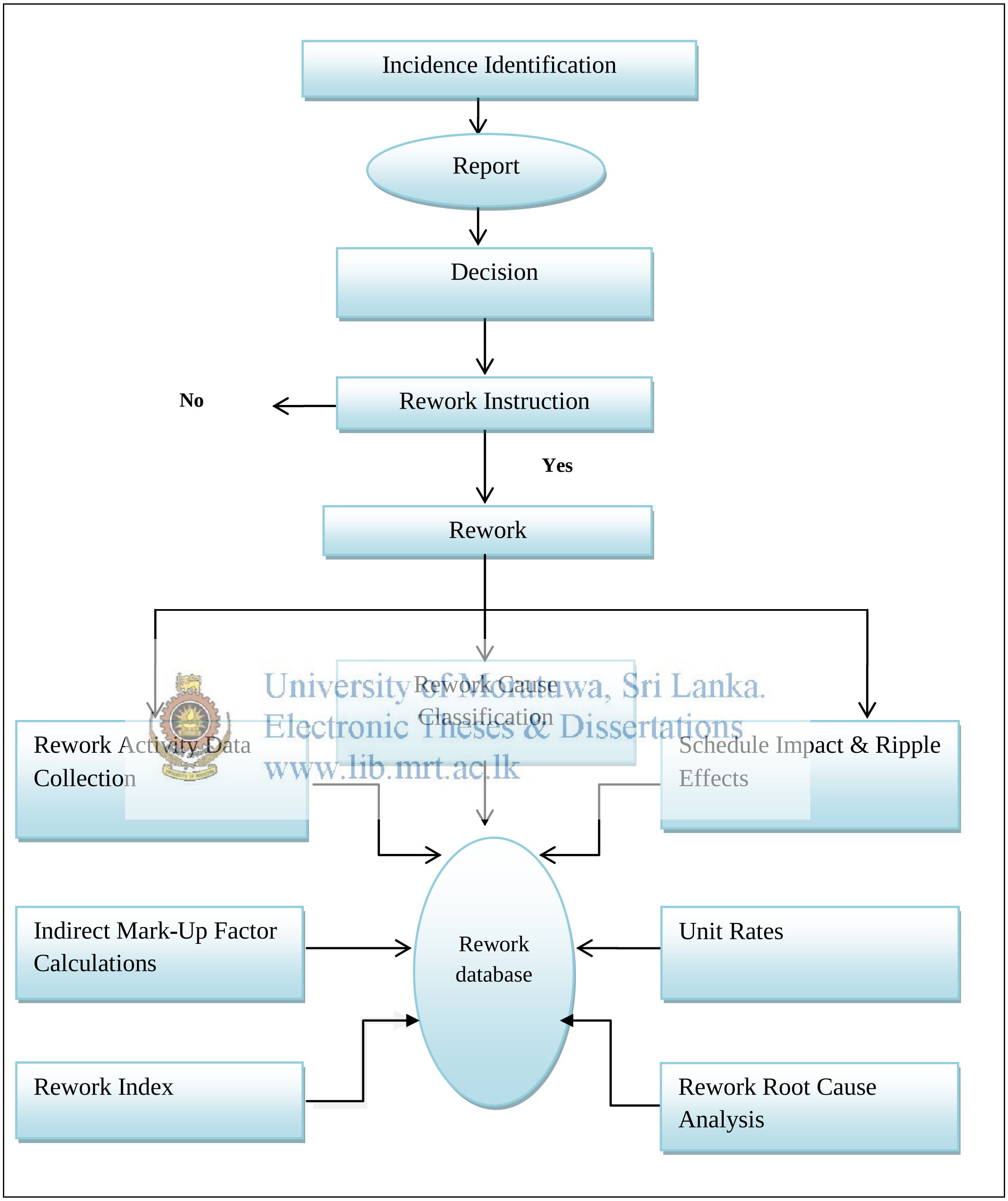

Figure: 2.1 Field Rework Tracking Process (COAA in 2003)

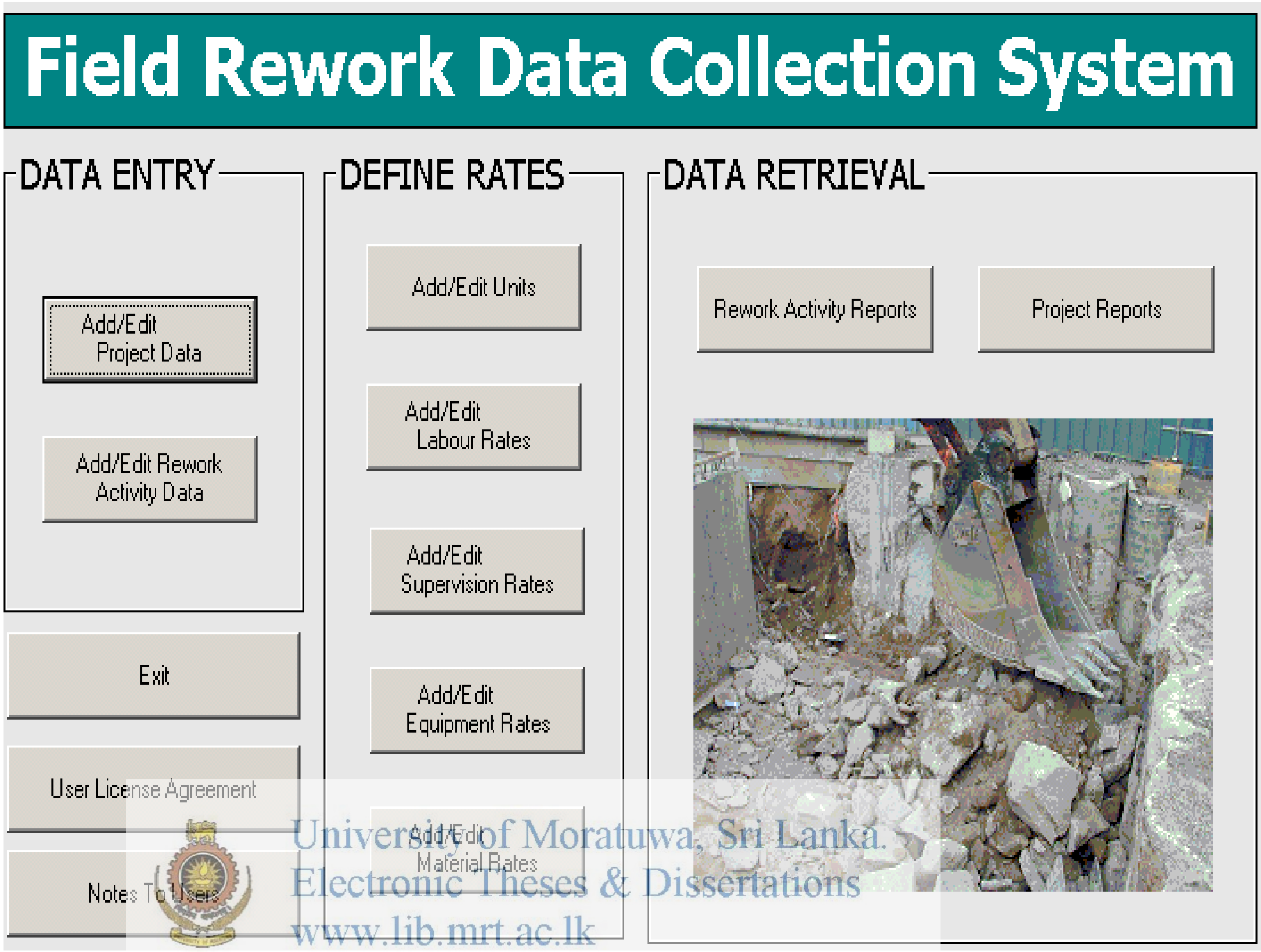

Figure: 2.2 Field Rework Data Collection System

(COAA in 2003)

Di Zhang (2009) used following rework tracking and cause classification to identify the rework occurrences and causes of rework.

This rework tracking determined, which activities are reworks and which type of conditions have resulted in the rework. The events should be documented and should especially include the time, duration, participants, labour hours, schedule shift, materials, equipment, and characteristics of the cause. The process is initiated by the workface supervisor, and the participants can include the site manager, site management team, project manager, and consultant engineer. All project personnel should be encouraged to record rework events.

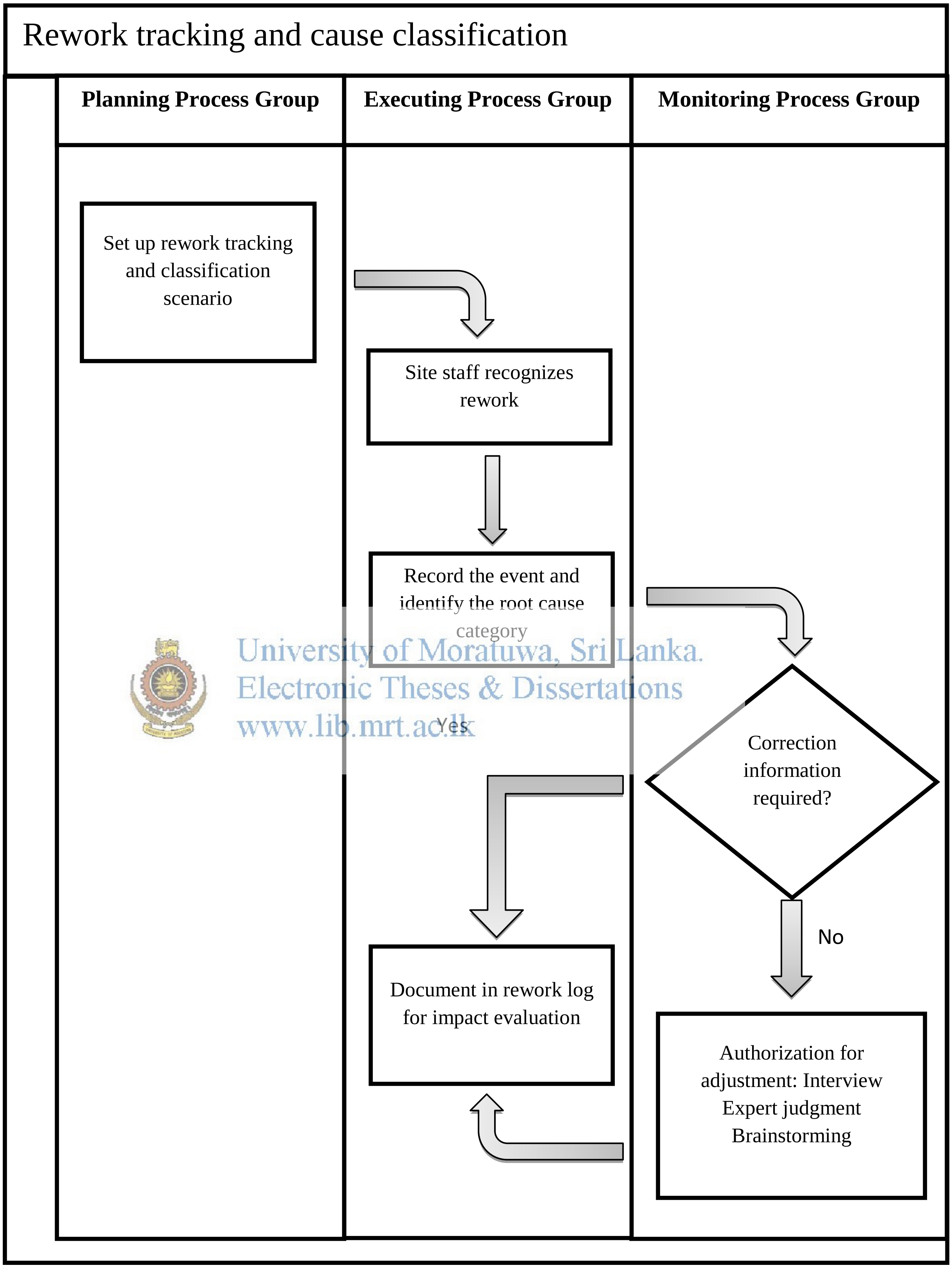

Figure 2.3 Rework Tracking Process (Di Zhang in 2009)

Di Zhan; Carl T.Haas; Paul M. Goodrum; Carlos H. Caldas; and Robin Granger (2012) identified a new rework tracking process. As shown in the Figure 2.4, it comprises of 3 identifiers which are elaborated in the chart.

Identifier 1: a certain product or process does not confirm to specification requirement

Identifier 2: extra material consumed in a certain process plan

Identifier 3: extra time spent in a certain process beyond plan

This identification did not directly determine a rework occurrence, but indicated that there could be rework needed to correct the non-conformance to specifications. Upon discovering the non-conformance to technical specifications, as the identifier 1 noted above, the resulting process involved.

If the relevant authority decided to do rework, they will issue instructions on the processes and will schedule time for accomplishing the rework. Necessary resources are assigned accordingly. The rework reporting is then started. This kind of rework, which follows instructions initiated by an inspection, can be noted as "post-inspection rework".

Sometimes site personnel will solve a rework event independently, which may involve unreported rework.For this situation, the identifier 2 and 3 (Figure 2.4) can be used to discover a non-conformance which may involve a rework event. If there are significant extra resources (extra material and extra time) spent in a certain work package beyond the necessary resources originally estimated and assigned, this adverse event must be reported. Project control personnel should ask the involved personnel for an explanation in order to determine whether a rework event occurred. This kind of rework can be noted as "pre-inspection rework".

It has been suggested that the only sustainable way to incentivize rework reporting is to create a culture that treats reporting as a normal and expected behaviour that is neither specifically rewarded nor penalized. This makes sense, but as an approach, it does not benefit from the moral imperative and the legal obligation that drives accident reporting. That is why the process described in Figure 2.4.

An essential impact element in this process in the Rework Cause Classification Structure provides a guidelines and structure for tracking and classifying the rework.An experiential, model-based, rework cause's classification structure was used, which synthesized the experience and knowledge from previous rework control practices for the modification and maintenance program of small projects that constitutes the data base used in this study.It is applied to the rework causes analysis in the following data analysis section.Similar classification structure was observed in the literature,which tend to reinforce the general applicability of the model described here (Fayeket al., 2004; Love et al., 1999) As already indicated, a rework reduction program must be a result-oriented system which means that the corrective action is based on the classification and measurement of the rework.

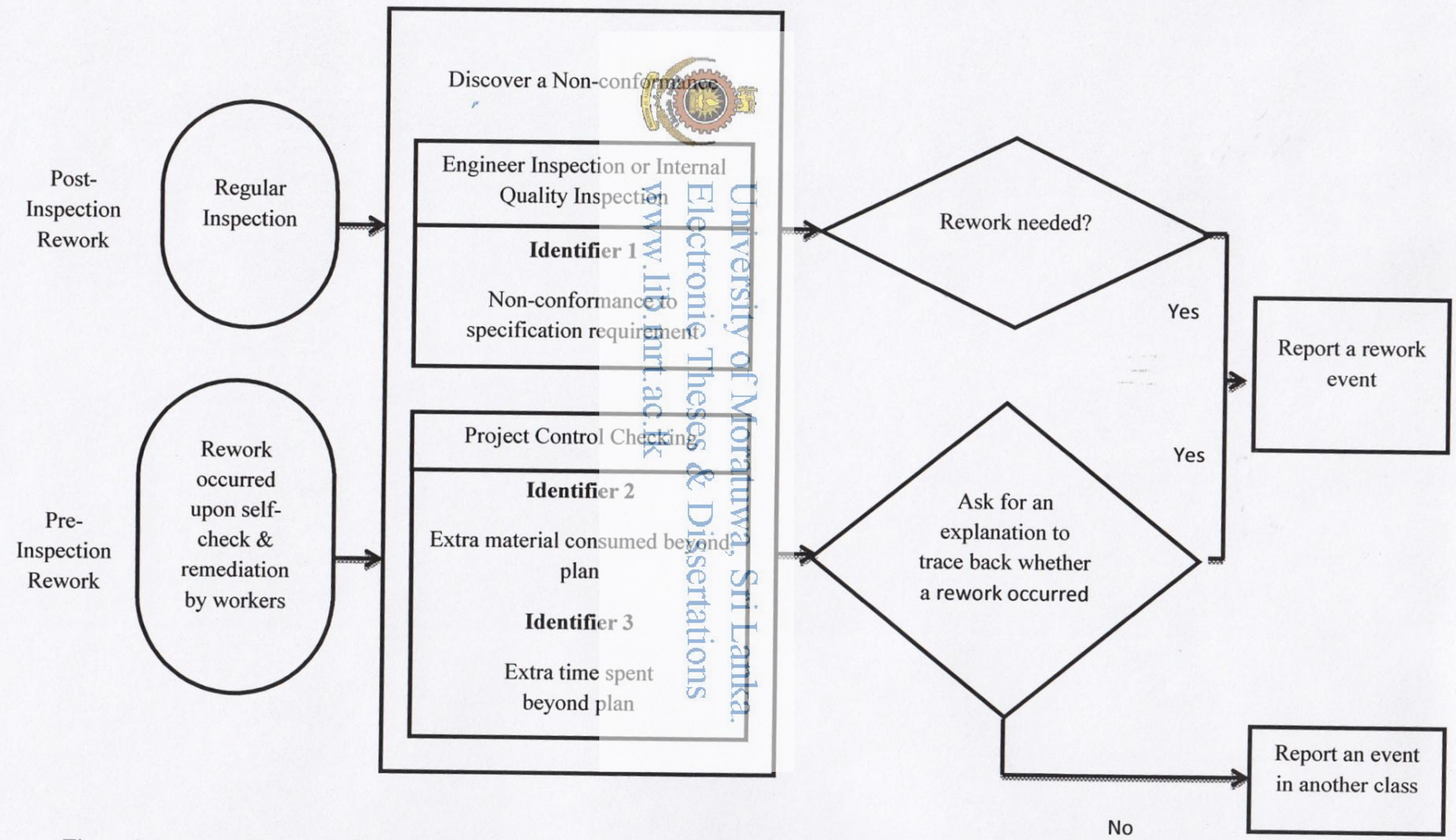

Figure 2.4 Rework Event Tracking Process (Di Zhan; Carl T.Haas; Paul M. Goodrum; Carlos H. Caldas; and Robin Granger in 2012)

2.5 Root Causes of Rework

Several researchers have extensively studied the causes and effects of rework in the building construction. They identified and elaborated root causes of rework differently under different categorizations.Almost all studies have reported that rework plays a major role in cost and schedule overruns. Therefore, the main root causes of rework identified as errors, omissions, failures, damages, defects, changes,non-conformance, poor leadership, poor communication and ineffective decision making.

Studies have emphasized the fact that more rework originated in the design stage than in the construction stage. The Building Research Establishment in the UK (BRE, 1981) found that 50 percent of the origin of errors in buildings occurred in the design stage and 40 percent during the construction stage. Burroughs (1993) reported that a major Australian Contractor had experienced rework costs amounting to 5 percent of the contract value in one of its major projects and these costs were attributable to poor documentation by design consultants. Many causes of rework thus originated during the design phase, the requirement of effective design management has been reported as a key factor in reducing rework.

Love and Edwards in 2004 categorized the root causes of rework in to different groups such as client-related factors, design-related factors, and contractor-related factors including site management and subcontractors. The client initiated rework symptoms were prevailed as the design changes and construction related changes which were initiated after some work had been undertaken or a product or process had been completed.

The client-related rework symptoms include:

1. Lack of experience and knowledge of design and construction process
2. Lack of funding allocated for site investigations
3. Lack of client involvement in the project
4. Inadequate briefing
5. Poor communication with design consultants
6. Inadequate contract documentation

This study also indicated that significant part of rework was design-related. The design related rework symptoms are the changes made by different parties such as clients, contractors/subcontractors, and end users/regulator bodies.

The design-related rework factors include:

1. Ineffective use of quality management practices
2. Ineffective use of information technologies
3. Poor coordination between different design team members
4. Time boxing/fixed time for a task
5. Poor planning of workload
6. Lack of manpower to complete the required tasks
7. Re-allocation of other projects
8. Incomplete design at the time of tender
9. Insufficient time to prepare contract documentation
10. Inadequate client brief to prepare detailed contract documentation

The subcontractor related factors that cause rework including damages, defects, poor workmanship, inadequate managerial/supervisory skills, use of poor quality materials and specific problems associated with layered subcontracting. Other symptoms and rework factors included constructability associated concerns, poor site conditions and other environmental parameters such as setting out errors, failure to provide protection to constructed works, changes in construction methods to improve constructability, errors due to inappropriate construction methods, omissions of some activities.

The National Economic Development Office in 1987 conducted a survey that aimed to identify ways of improving quality control in building works. As it revealed, the main factors that influenced quality were attributed to design such as lack of coordination of design, unclear and missing documentation and poor workmanship such as lack of care, understanding and knowledge.

J.T.O.Connor in 1985 had suggested that the use of constructability analysis significantly reduced design and construction-related rework. Constructability was a strategy that could be used to achieve optimum integration of construction knowledge throughout the procurement process as well as to balance various project and environmental constraints so as to maximize project goals and project performance. This was done by using the knowledge and experience of key design and construction personnel during the design process so as to improve teamwork, and planning and scheduling of site operations, which in turn could translate into ameliorated project performance in terms of time, cost, and quality.

Projects where constructability has been specifically addressed have reported saving of 6%-10% of construction costs (Construction Management Cost of the ASCE Construction Division in 1991).Similarly, valuemanagement also used to minimize design changes and errors. However, clients were reluctant to practice this technique which required additional cost.

As the study conducted by G.Rounce in 1998, it was revealed that inadequate time to prepare complete design documents led to poor planning of workload within the design organizations. Also, inexperienced staff having lack of technical knowledge led to errors and omissions in contract documentation. He identified a number of poor management practices that contributed to the generation of rework and waste in architectural firms.

These included the following,

- Jobs not having projected drawing lists to quantify the design workload;
- Jobs not having design programs based on project drawing lists and, therefore, specific design deliverables are unable to be identified;
- Difficulty in estimating the physical progress of the design;
- Uncertainty in advising other designers/quantity surveyors when information is likely to be available ;
- Difficulty in justifying resources required to in house managers based on actual workload;
- Lack of specific procedures (non-administrative) generally to control the design process in program terms.

Furthermore, it was revealed that the increased client demands for earlier project completion was another factor that has been identified as a major contributing factor to the production of incomplete and erroneous contract documentation. This has contributed to reduce profits in architectural firms due to,

Redesign due to an inadequate brief;

- Changes arising from unchecked drawing issue;
- Redesign due to inappropriate drawing scale;
- Attending to design changes requested by the client.

Rounce (1998) recommended that architectural firms would be ameliorated their internal management practices through quality management, particularly quality assurance (QA), if their profitability was to be improved. If this is done effectively, then Rouncealso suggested that architectural firms would see non-conformance cost as a percentage of their fee for a project, could be reduced by as much as 45%.

Cusack (1992) suggested that the major cause of rework in a project was related to documentation errors, noting that projects without a quality system in place in terms of maintaining documents, typically experienced a 10 percent cost increase because of rework.

Gardiner (1994) estimated that the cost related to the rework of design consultants could be as high as 20 percent of their fee for a given project.

Koskela (1992) suggested that it seemed that the wastes caused by design were larger than the cost of design itself, and he further stated that even if there was a lack of data on internal waste in design, it could be inferred that a substantial share of design time was consumed by redoing or waiting for information and instructions.

Powell (1997) has suggested that the insularity and aversion of architectural firms to discuss with peer management in other discipline has resulted in poor services quality and their marginalization within the industry. While architectural firms have been identified as the primary source of the design-related rework experienced in projects, other firms, such as consulting engineers, contractors, and project managers, who are integral to the procurement process, are also prone to cause poor managerial practices in the project (Love and Sohal 2000).

Hammarlund and Josephson opined the sources of quality failures in a building project and found the costs of correcting failures to be 6 percent of production costs. Moreover, the time taken to rectify these errors was estimated to be 11 percent of the total working hours allocated for the project. They suggested that a large part of the failure costs were attributable to the poor skills of site management. Their study found the major causes of quality failures in order of precedence to be defective workmanship, defect in product, insufficient work separation, inadequate construction planning, disturbances in personnel planning, delays, alterations, and failures in setting out and coordination. Quality failures that have occurred have been estimated by Hammarlund and Josephson to be as high as 4% of the actual project's production cost. Interestingly, 51% of these failure costs were found to be design related, while 26% were related to poor installation of materials and 10% to material failure.

Abdul-Rahman (1993), in a study of non-conformances in a water treatment plant, identified 62 non-conformances accounted for 2.5% of contract value, although all non-conformances couldn't be identified due to study resource constraints and availability of site research personnel. Therefore, he stated that the rate at which the costs of non-conformances would be6% of the estimated project cost if rework was constant throughout the construction. This figure, however, did not reflect the full extent of rework that occurred, as many client-initiated variations could not be included inanalysis. Abdul-Rahman (1993) also revealed that design errors or omissions contributed to 30%of the cost of non-conformances and, the major construction-related costs of non-conformances were described as subcontractor, coordination, planning, and construction. The same study examined the incidence and cost of non-conformances in a highway project, 72 non-conformances were identified, 59 of which were used in the analysis because those excluded were of a trivial nature and did not carry costs. Non-conformances found were to account for 5% of the contract value and were primarily attributable to subcontractor-, construction-, and design-related issues.

Burati et al. (1992) collected data on quality deviations from nine industrial engineering projects and found that the cost of quality deviations could be as high as 12.4% of project cost. Furthermore, 79% of total deviation costs were created during design, compared to

17% for construction deviations. Such deviations in cost could be even higher because they do not represent schedule delays, litigation costs, and other intangible costs of poor quality. Davis and Ledbetter (1987) have noted that rework costs are only the “tip of the iceberg,” as many other impact costs were associated with rework and lack of quality management.

CIDA (1995) found that poor communication inthe use of traditional lump-sum procurement system were major factors that contributed rework in Australian projects. They reported that rework costs for traditional lump-sum methods exceeded 15% of a project’s contract value, and moreover, formal quality management system in place recorded significantly lower levels of rework. While previous research had sought to determine the direct (tangible) costs of rework, the indirect (intangible) costs remain unexplored in construction (Love 2002b). Bower sox et al. (1985) Estimated that the cost of rectifying a poor quality product or service could be more than eight times of its original cost. Accordingly, Love (2002a) reported that a multiplier effect of at least five was directly related to the indirect effects of rework incidents in construction.

Josephson and Hammarlund (1999) found the cost for defects in seven Swedish building projects ranged from 2.2 to 9.0% of the contract value. They also found that 50% of the total costs of defects originated on site, with further 32% originating from the client or design inconsistencies, and that the root cause for 40% of defect costs was due to poor motivation levels in the site workforce.

Furthermore, empirical studies sought to determine the learning practices used by construction firms andestablished how effective they were in improving organizational performance.

Nesan& Holt in 1999, considered rework as a quality management problem. Construction firm reduced the amount of rework they experienced, then they needed to re-examine the way they conducted business by proactively embracing quality management. For example, architectural firms should strive to eliminate unnecessary drawing revisions and work to a structured program identified specific design deliverables. Also care is needed to be taken to minimizing variable that contributed to poor performance.

Jaafari (1996) suggested that the QA practice developed by contractor, had tended to be passed on post-production quality control, and as a result, increased costs without commensurate savings or benefit to the firm. Lomas (1996) of Barclay Construction Ltd, (Australia) reported that rework costs were estimated as 5% of the contract value prior to the implementations of the QA system. However, once QA was implemented rework was less than 1% of the contract value in almost all projects. Lomas found that QA contributed to an aggregate saving to the company in excess of a $4.2 million in 1996, which was approximately 1% of its turnover.

The issue of QA, however still a contentious issue within the Australian construction industry (Chan, 1996; Karim, Marosszkey, Chung, Kurmaraswamy& Low 2000). To have any chance of gaining government contract, consultants and contractors were required to show that they have been given the “quality stamps of approval.” In essence, becoming certified to a recognized standard has become a matter of survival for many design and construction firms. For some firms, certification has become an end in itself, rather than means of implementing an ongoing quality system, which seek sustainable continuous improvement (Dissanayaka, Kurmarawamy, Karim, &Marosszkey, 2001). There are many firms in the construction industry that have started out with the best intentions regarding the use of certification. Yet, the documentation requirements and administrative overhead of the ISO standards have been found to be extremely onerous and bureaucratic for many construction firms (Kurmaraswamy, 1996; Love & Li, 2000; Low & Omar, 1997).

The requirements of ISO 9000, and more recently the ISO 9000:2000 series, required their own documentation and procedures. If both were not effectively maintained, then firms might find themselves being channeled into managing the documentation of the certification process, rather than into achieving the objectives of the quality system itself. Equally important, staff motivation became a serious problem since staff tends to review certification as a necessary non-productive evil and might re-sent the extra paperwork imposed upon them (Love & Li, 2000).

Low and Chan (1998) suggested that the implementation of effective quality system alongdiverse management factors such as support of senior management, appropriate leadership style, the cultivation of employees' behaviour and attitude, open communication and feedback must be considered.

Buta and Karkhanis (1996) found that many Australian construction firms embraced quality certification to initially reduce their incidence of rework and improve their marketing.

Many small and medium-sized construction firms in recent years voiced their concerns over the difficulty and cost of introducing an ISO quality system (Buta&Karkhanis, 1996; Karim, Marosszkey, Chung, Kurmarawamy& Low, 2000). However, Gnome (1995) contended that the ISO 9000 series was irrelevant to smaller organization as a high cost associated with achieving and maintaining a certification program could significantly damage their business. In fact, Gnome went as far as starting that ISO 9000 requirements were far too sophisticated and did not add value to small- and medium-sized businesses. The direct costs of obtaining and maintaining ISO certification include associated registration fee, auditing fee, and optional consultant fees (Love & Li, 2000).

The internal auditing process for ISO could be used as a tool contributing to continuous improvement. If used effectively, the auditing activity could facilitate process improvement by identifying poorly performing activities that contribute to the occurrence of rework in a process. Corrective action analysis could be used to determine the causes of rework in a process. Rework causes would influence the appropriate actions to be undertaken to solve the problem. In this way, the internal audit process associated with ISO 9000 to be used for sustaining continuous improvement.

Landin and Nilsson (2001) stated that construction firms investments in quality systems based on "acts of a faith," rather than on factual information. Consequently, they were often left questioning how much quality was actually costing or saving them. In particular, many Australian design and construction organizations have limited knowledge about their rework cost (Tucker et al, 1996).

To understand such cost, it was suggested that quality costing should form an integral part of a firm's and a project manager's approach to managing quality costs (Low &Yoe, 1998). To do so, it was necessary to implement systems to collect, measure, and analyze quality. This formed management about quality failures (or rework) and the activities that need to be designed to prevent their future occurrences. This information helped to determine quality improvement initiatives, which could be directed in achieving significant cost saving and quality breakthroughs.

Adobbin (1975) suggested that quality-related costs typically range from 5% to 25% of an organization's annual turnover or operating costs. Of this cost, 90% was expended on appraisal and failure costs (Hagan, 1985). Reducing failure costs by eliminating their causes could lead to substantial reductions in appraisal costs. Indeed, according to Dale and Plunkett (1990), quality cost be reduced by one third when a cost–effective quality management system is implemented. The measurement of quality failures in construction, however, can be considered after-the-fact inasmuch as it occurred after the activities have occurred (Love & Li, 2000). Therefore, measurement should be used to learn from the post to improve the future performance of the firm, and resulting project.

Organizational learning defined as "the process of improving actions through better knowledge and understanding" (Fiol& Lyles, 1995). Garvin (1993) stated that if TQM was practiced as a philosophy (i.e., continuous improvement), as well as a set of learning techniques (i.e., Plan-Do-Act-Check Cycle), then it could be used as an enabler for organizational learning at both an individual and group level.

Nesan and Holt (1999) pointed out that successful organizationswere able to learn as a collective entity, as well as at the individual levelLuthans, Rubach and Marsnik (1995) stated that learning was an essential tool for addressing improvement initiatives and therefore a key source for gaining a competitive advantage. Hence, if construction firms were to reduce the amount of rework they incurred (particularly from failure), then they should consciously endeavour to improve their "learning capability" by embracing mechanisms to stimulate organizational learning. Kululanga, Edum-Fotwe, McCaffer and Price (1998) described types of learning (individual and organizational) activities included internal and external benchmarking, collaborating with other organizations, continuousprofessional development (CPD), research and development, project reviews, internal seminars and self-learning.

2.6 Classification Causes of Rework

There are several main different types of rework causes classification systems identified from the literature.One study involving nine industrial construction projects done by Burati et al. (1992), the classification of rework causes were identified in the form of deviation categories listed in Table 2.1.

Deviation Category	**Description**
Construction Change	Change in the method of construction
Construction Error	Results of erroneous construction methods
Construction Omissions	Omissions of some construction activity or task
Design Error	Error during design
Design Omission	Omission made during design
Design Change/Construction	Changes in design at the request of field/construction personnel
Design Change/Field	Changes by the designer due to unforeseen field condition
Design Change/Owner	Design change initiated by Owner(Scope Definition)
Design Change/Process	Design change in the process, initiated by Owner/designer
Design Change/Fabrication	Design change initiated or requested by fabricator or supplier
Design Change/Improvement	Design revisions, modifications, and improvements
Design Change/Unknown	Redesign due to an error
Operability Change	Change to improve operability
Fabrication Change	Change during fabrication
Fabrication Error	Error during fabrication
Fabrication Omission	Omission during fabrication
Transportation Change	Change to the method of transportation
Transportation Error	Error in the method of transportation
Transportation Omission	Omission in the transportation

Table 2.1: Categories of Deviation that Causes Rework(Burati et al. in 1992)

Secondly, Love et al. in 1997 identified a rework classification system basically studying of two construction projects. This classification called Cause and Effect Diagram was done according to the three principal groups; namely, People, Design, and Construction involved for the construction, as illustrated in Figure 2.5

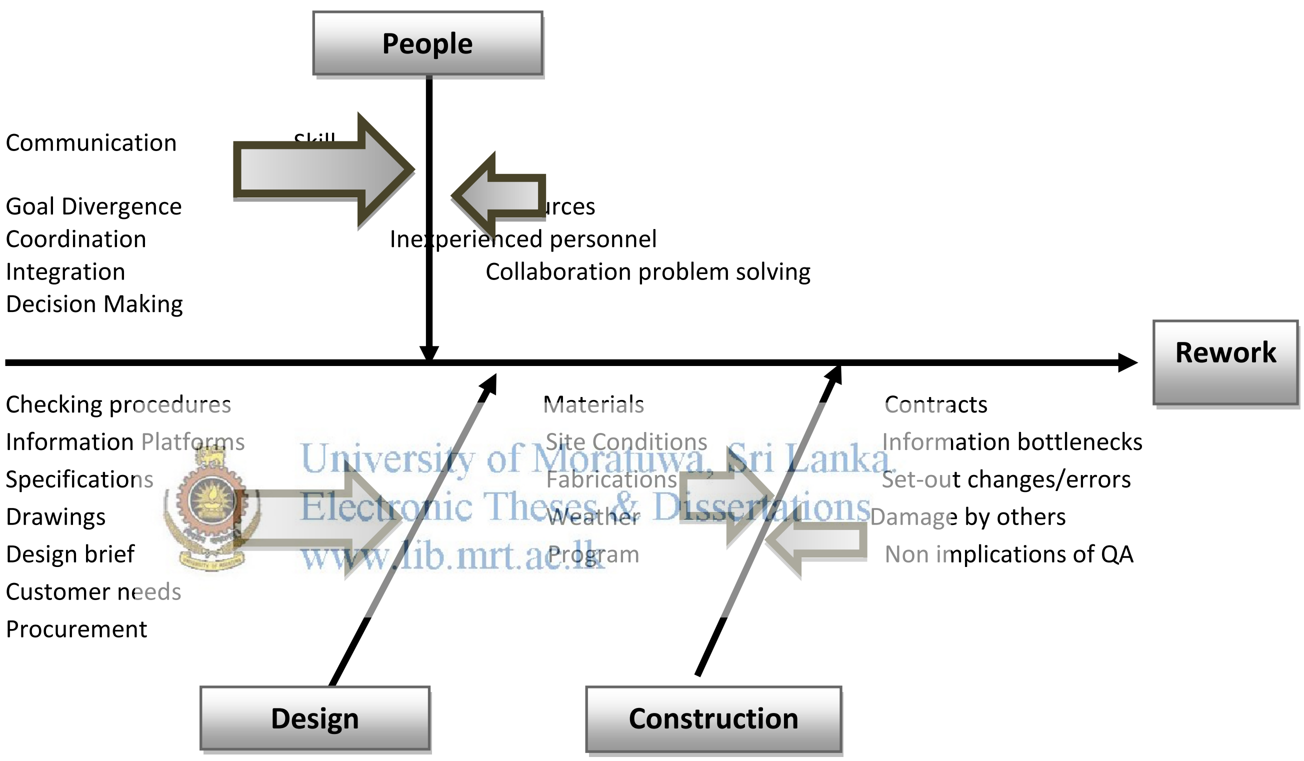

Figure 2-5 Generic Cause and Effect Rework Diagram (Love et al. in 1997)

Thirdly, Love and Li in 2000 represented another classification to quantify the causes and costs of rework based on Burati et al.'s classification model. Rework was classifiedintothree categories; namely, client initiated changes, non-variations, and defects using data collected from the construction phase of the project. This study also showed productivity-time counting or non-contributory work, which refers the loss of time due to waiting, being idle, travelling, and re-doing work.

As a fourth, Fayek et al. in 2003 determined five major causes of rework; namely, human resource capability, leadership and communication, engineering and reviews, construction planning and scheduling and material and equipment supply. The classification of rework causes based on the above major causes was represented in a fishbone diagram highlighting all possible and actual causes of rework. The fishbone diagram consists of five basic sources of rework with four possible sub causes in each of the basic sources. Shown in figure 2.6

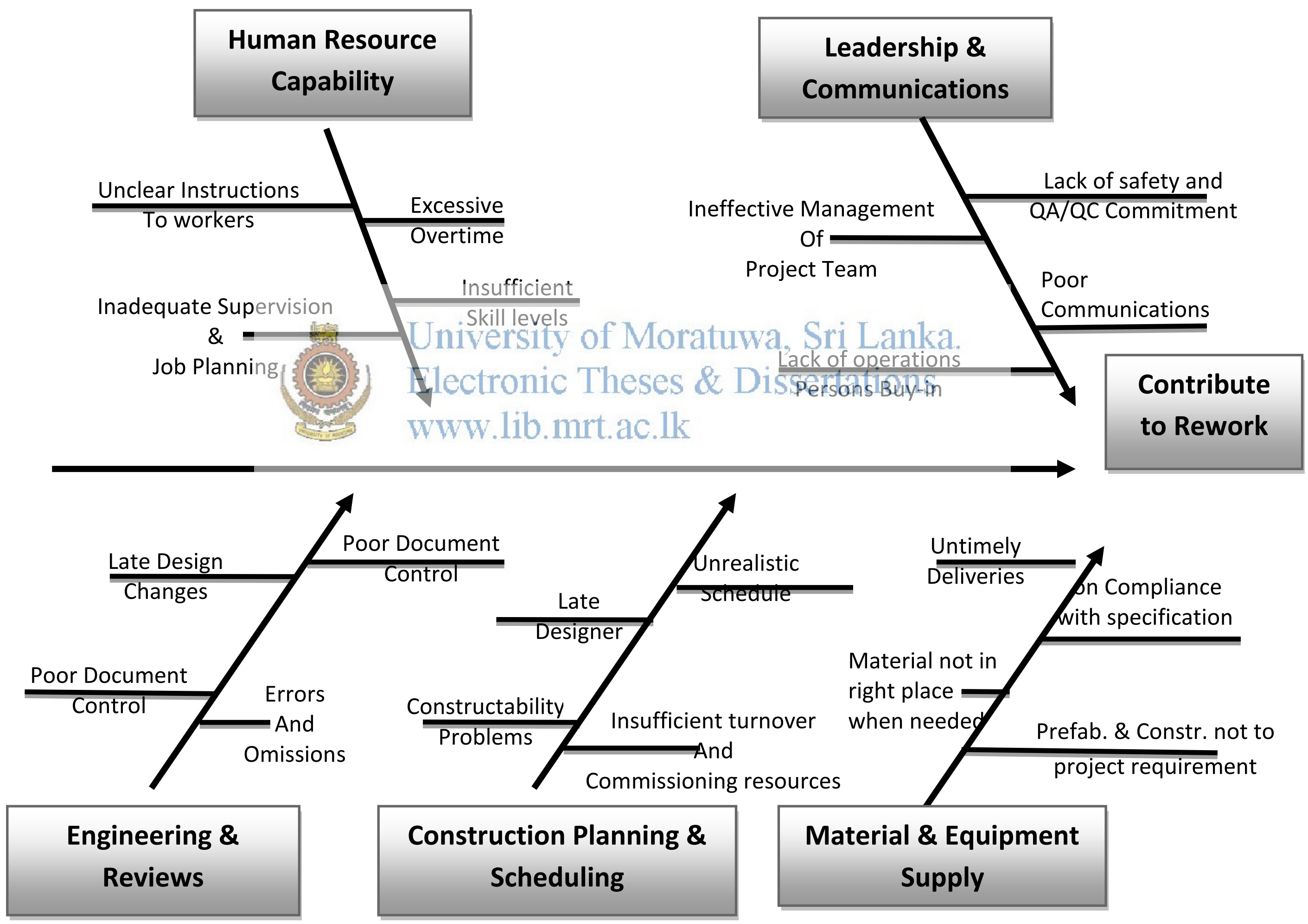

Fig 2.6: Fishbone Classification Model of the Causes of Rework (Fayek et al., 2003)

Fayek et al. in 2004 represented the classification system based on the two criteria distinguishing the contribution of a variety of causes of rework; namely, the frequency of occurrences and the monetary value of rework-related cost increase using major causes of field rework identified as the outcome of a pilot study of rework in a mega industrial project in Alberta. They were human resource capability, leadership and communication, engineering and reviews, construction planning and scheduling and material and equipment supply.Following table has used to enter data collected.

Root Cause	**Classification based on:**	
	Freq. of occurrences %	**Monetary value %**
Engineering and Reviews		
Human Resource Capability		
Material and Equipment Supply		
Planning and Scheduling		
Leadership and communication		

Table 2.2: Classification of Rework Causes (Fayeket al.2004)

Love et al. in 2003 done another interesting study, the causes of rework were grouped into categories based on the initiator of the cause. The ranked causes within each category are shown in table2.4.

Category	Rank	Cause
Design Causes	1	Changes made at the request of client
	2	Errors made in contract documentation
	3	Omissions of items from contract documentation
	4	Changes initiated by end-user/regulatory bodies
	5	Changes made at the request of the contractor during construction
	6	Modifications of the design initiated by the contractor or subcontractor
Construction Causes	1	Changes initiated by client after some work had been undertaken on site
	2	Changes initiated by client or occupier after some work had been completed
	3	Changes in construction methods due to site conditions
	4	Changes in method of construction to improve constructability
	5	Errors due to inappropriate construction methods
	6	Damage caused by subcontractor
	7	Omission of some activity or task
	8	Changes initiated by contractor to improve quality
	9	Changes made during manufacture of product
Client Cause	1	Lack of experience and knowledge of design and construction process
	2	Payment of low fees for preparing contract documentation
	3	Poor communication with design consultants
	4	Inadequate time and money spent on briefing process
	5	Lack of funding allocated for site investigations
	6	Lack of client involvement
Design Team Cause	1	Ineffective use of information technologies
	2	Staff turnover/allocation to other projects
	3	Incomplete design at time of tender
	4	Insufficient time to prepare contract documentation
	5	Poor coordination between design team members
	6	Poor planning of workload
	7	Ineffective use of quality management practices
	8	Time Boxing
	9	Lack of manpower to complete required tasks
	10	Inadequate client brief to prepare detailed contract documentation
Site Management Cause	1	Poor Planning and coordination
	2	Ineffective use of quality management practices
	3	Setting out errors
	4	Ineffective use of information technologies
	5	Staff turnover/allocation to other projects
	6	Failure to provide protection for construction work
Subcontractor Cause	1	Ineffective use of quality management practices
	2	Inadequate managerial and supervisory skills
	3	Damage to other trades due to carelessness
	4	Low labour skill level
	5	Use of poor quality materials

Table2.3 Rework Cost Categories caused (Love et al, 2003)

Love et al. in 2004 found that the primary factors contributing to construction field rework as shown in Table 2.5 based on the facts of several studies.

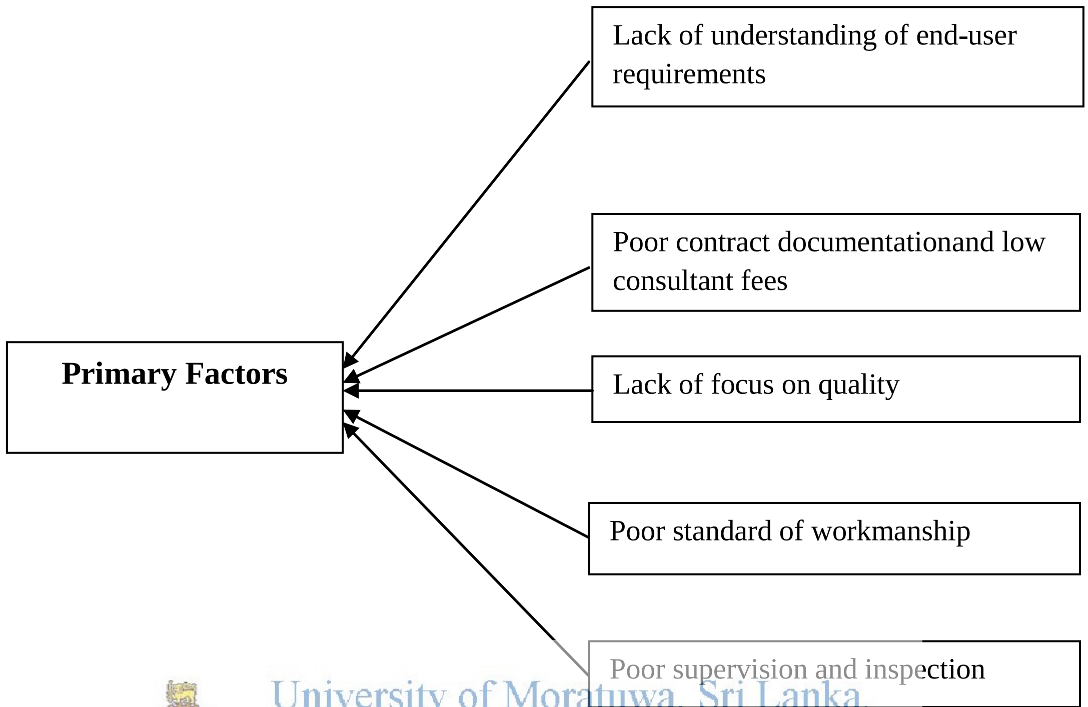

Figure 2.7: Primary Rework Factors (Love et al. in 2004)

Di Zhang (2009) used following cause classification structure to identify the causes of rework and to find proper corrections for rework.

The cause classification structure which was combined the with experience and knowledge from relevant literature and rework practice in actual projects, based on two considerations: one was the requirements of the management level, and the other was need for the designed categories to be related to the executive group, technology, and schedule required for the implementation of the corrective action.

The ultimate purpose of the rework classification and measurement system was to provide a direction for remedial action for the rework problem.

From a performance management perspective, the factors that influence performance are normally categorized according to three management levels: organizational, process and job/performer. The organizational level encompasses many variable factors, including non-productivity factors, which are not within the scope of this research. It is assumed that the organizational structure and group are built appropriately for project performance. The factors in this level were therefore not considered in the classification of the causes of rework used in this model, as shown in table 2.4. The sub-causes are related to the consideration of the deficiencies of performance to be related to the executive group, circumstance of construction, technology and schedule that could cause rework activities.

Rework Root Causes		**Description(or Sub-Causes**
Process Group		
1	Design and Engineering	Drawing and specification errors or omissions
		Deficiencies in documentation control
		Scope and Design changes
		Lack of attention to detail
2	Instruction and Inspection	Ineffective communication
		Poor decision making process
		Poor monitoring and control
3	Schedule	Deficiencies in forecasting field condition
		Poor scheduling of construction resources
		Poor development and application of realistic work procedures
4	Material and Equipment Supply	Untimely deliveries or misplacement
		Defects in prefabrication
		Equipment and tools not sufficiently advanced
Human Performance Group		
5	Knowledge	Inadequate knowledge of action required to complete task successfully
6	Skill	Lack of domain-specific skill
		Deficiencies in personnel training
7	Self-discipline	Violation of rules or policy failures to adhere to work
		Instructions or procedure
		Lack of motivation

Table 2.4: List of Identified Root Causes of Rework(Di Zhang in 2009)

2.7 Rework Reduction Tools

There were several rework reduction tools found from the literature. The COAA was developed the PRRT (Project Rework Reduction Tool) which was a management tool to facilitate project performance against known rework-causing issues. It was expected that the rework in project execution could more often be averted if these deficiencies were recognized early in the project.

The tool was designed to take the evaluation of field rework and rate it on key field rework causing factors. The evaluation could be applied at any point in the project's timeline. The ratings were interpreted within the 5 principal Rework Cause sections of the COAA fishbone classification of field rework cause.The overall average rating may be used for trending and benchmarking against similar projects, while the suggestion for practical solutions was given to improve future works. (COAA, 2006)

The PRRT can be used to carry out project health checks by making evaluations, rating key field rework causing factors, and by suggesting practical solutions to improve future ratings. The tool functions through the project ratings given by a user in response to a multiple-choice questionnaire.

Powell in 1995 was designed the rework reduction program model as a secondary supportive management program to be used at the level below the total quality management program in the company's management strategies (see Table 2.5). The program implemented the specific remediation task to reduce rework in construction performance. It was a long term program taking into account and intended to impact all ongoing projects of the company.

The purpose of the rework reduction model was to track construction rework, to decrease the occurrence of rework and its adverse impact on project performance and to improve productivity.

No	Management Level	Content
1	Enterprise Strategies	Performance Management, Total Quality Management, Supply Chain Management ,Human Resource Development Strategy, Financing Strategy
2	Specific Management Program	Rework Reduction Program, Corrective Action Plan, Zero Defect Performance
3	Project Execution	Quality Control, Schedule Control, Cost Control, Risk Control, Scope Management, Procurement Management
4	Techniques	Cause and Effect Analysis, Impact Matrix, Human Performance Techniques, Work Break Down Structure, Earned Value Management, Computer Aided Tools

Table 2.5 Rework Reduction in the Management Hierarchy (Powell in 1995)

This Rework Reduction program includes the following processes:

1. *Rework tracking and cause classification*: detecting and identifying the rework that occurs in the defined work scope and identifying the causes of the rework
2. *Impact evaluation and trend analysis*: conducting data fusion and quantifying the impact of the rework on project performance in terms of cost, schedule, and quality and identifying trends in the impact over time as well as the causes
3. *Corrective action planning*: developing options and actions that will bring about changes in the project management system with the goal of reducing construction rework
4. *Intervention and integration with the project management system*: integrating the input, output and functions of the rework reduction model into the project monitoring and control process, using the information system as the platform for the integration.

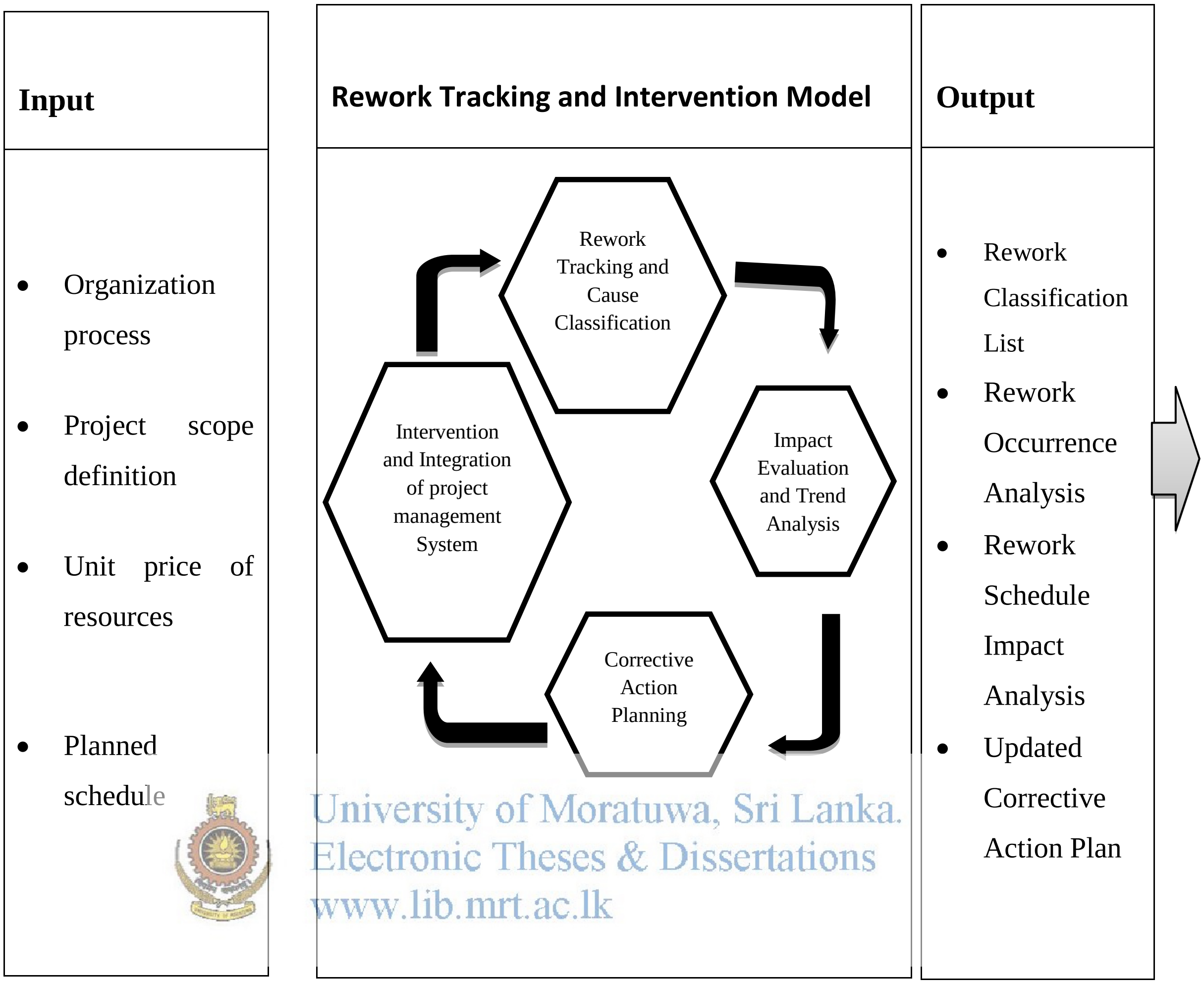

Figure 2.8 Process Flow Chart of RRP (Powell in 1995)

Another Rework Reduction Program was developed by Di Zhang and Carl T and Haas in 2012 and it was almost similar to the programmed developed by Powel.A Rework Reduction Program was a supportive management program to be used in conjunction with other initiatives as part of a company's management strategies. Such a program implements the specific remediation task to reduce rework in construction. It was a long term program that takes into account and is intended to impact all ongoing projects of the company. The purpose of a rework reduction program was to track construction rework and to decrease the occurrence of rework and its adverse impact on project performance, especially in terms of productivity. This model includes the following functions:

- Identify the construction field rework
- Determine and classify the rework root causes
- Document the rework events and deliver the rework lessons to the relevant group
- Quantify the impact of the rework on project performance
- Develop a corrective action plan to eliminate the cause
- Plan an updated improvement scenario for changes to the project management system
- Implement the corrective action plan
- Verify the effectiveness with respective to eliminating the causes

This model was intended to be used to reduce rework by managing a continuous improvement loop with four sets of processes. They are Rework tracking and causes classifying, Impact evaluation and trend analysis, Corrective action planning, Intervening and integrating to project management system.

2.8 Impact of Rework on Project Performance

As far as the impact on project performance due to rework is discussed, quality, schedule, and cost are the three main elements commonly used to describe it. The most direct and perspicuous metric for elaborating the impact of rework is the related cost of rework which is also the most easily measured operational approach studied in different aspects by most researchers. Researchers who have studied the causes of rework and different aspects in relation to the construction have almost always investigated the direct cost of rework as a percentage of the actual value of the contract (Love & Shoal, 2003).

Several studies in literature have focused on analyzing the impact of rework on construction projects and on the whole construction industry. Josephson and Hammarlund (1999) reported that the cost of rework in residential, industrial, and commercial building projects ranged from 2 per cent to 6 percent of their contract values. Similarly, Love and Li (2000), in their study of rework costs for residential and industrial buildings, found the cost of rework to be 3.15 percent and 2.40 percent of the contract value respectively. Further studies on rework cost, Love and Li (2000) found that when a Contractor implemented a quality assurance system in conjunction with an effective continuous improvement strategy, rework costs were found to be less than 1 percent of the contract value.

Two key research studies have indicated the cost of quality deviations in civil and heavy industrial engineering projects. First, the study by Burati et al. (1992) of nine major engineering projects indicated quality deviations accounted for an average of 12.4 percent of the contract value for all nine projects; second, a significantly lower figure was reported pertaining to the quality by Abdul-Rahman (1995) and he pointed out that non-conformance costs may be significantly higher for projects characterized by poor quality management.

Smith and Haggard in 2005 showed that the overall range of field rework reported in surveys was from 0.5 percent to 19 percent with an average rate of 3.13 percent. The surveys collected significant amounts of data from 22 projects, which involved a variety of functional types of projects and included conditions associated with either Greenfield projects or modification and maintenance projects. These figures categorically illustrated the fact that additional costs due to rework had a considerable adverse impact on project performance. In addition to the impact of cost on project performance, the additional time required to redo the work would also result in a time shift or delay would probably affect the project schedule.

Rework is a significant factor that contributes negatively to the construction process, directly leads to client dissatisfaction and reduces profitability and it, in extreme conditions, leads to acrimonious relationship between participants which would be settled through either a recourse to law court or arbitration (Love, 2002).However, a reduction in rework can be significantly improved the overall project performance (Love et al, 2000; Low and Yeo, 1998).Love et al in 1999 concluded that causes of rework in various countries differedin the backdrop of conditions of contract and therefore, the costs of rework between countries should not be considered authoritative, but merely indicative, as levels and interpretations of quality will differ between each country. Local practices, industry culture, and contractual agreements contribute immensely to the incidence and cost of rework in any situation and environment (Love et al., 1999).Therefore, the paper evaluated the effects of project types on the occurrence of rework in expanding economy with the mind that the result of the research would be widely applicable in other nations.

Ibrahim et al. (2008) opined that the use of virtual reality models and 3D animations could be a useful tool in communicating constructability problems which was the major course of rework at design-construction interface by leading to better understanding of design information, thus, reducing waste, rework and ultimately cost of projects. Also, this assertion was supported by (Enache-Pommer and Horman,2009) they suggested that integrating the sustainable project's objectives with other delivery aspects during programming of design and construction will eventually results in reducing delays, costs, and rework on the project.

From many reported cases, it could be asserted that rework have negative impact on the performances of projects in terms of costs overrun, time overrun and dissatisfaction of the participants especially the client on the project. Palaneeswaran in 2006 argued that the direct impact of rework on project are enormous due to additional time to carry out the rework, additional cost to fix the defect plus related extensions of manpower supervision.

Hence, if rework is to be reduced or avoided, there isa need for clients' unnecessary involvement on construction activity to reduce changes or alteration to design after the commencement of work.

Christopher et al. (2009) argued that decision changes were capable of creating waste, such as rework, and that considered commitments upon which subsequent decisions could rely.

It was reported that the actual cost of rework for a contractor value (Love et al.,1998), and that a contractor will variably always try and off load any additional costs on to their client and subcontractors. In fact, a contractor's estimate/tender figure may also allow for some degree of rework (in the form of contingency) based on their knowledge and experience from previous and similar projects they have undertaken. Thus the actual cost of rework to a contractor may even be negligible, especially projects procured under a design and construct arrangement with a guaranteed maximum price (Love et al. 1998).

2.9 Literature Review Summary

Most studies have conducted an appropriate evaluation of rework tracking and data collection methodology, classification of rework root causes, rework reductions and impact of rework on project performance. Their achievements can be summarized as follows:

1. The above researches classified the root causes of rework and conducted quantitative analysis of the causes, in order to determine the most direct and effective approach to mitigating the occurrence of rework. Since the studies approached the control of rework from different perspectives, different breakdown structures were used to sort the categories of the root causes of rework. However, several common aspects were also addressed:
   - Human performance is imperfect.
   - Instructions are sometimes inappropriate or incorrect.
   - Supplies are sometimes not accurate or prompt.
   - The schedule is sometimes not rational.

   Summarizing the causes of rework that were listed in the literature was helpful for classifying the causes of rework for this study. This information was required for the design of the model because an important principle was the planning of corrective action based on the classification of the causes.

2. In project based transactions, any occurrence of rework is mainly considered as unnecessary /redundant non-value adding item that should be mostly avoided if not completely eliminated. Apparently, the rework impacts on performance and productivity aspects have been somehow 'tackled' by adopting various tactics and measures such as through contract management, quality management, project management, and value management.

3. Most of the research used the direct cost as the essential factor for evaluating the impact of rework. According to the result, the cost consumed through rework was quite significant and couldn't be neglected. It was widely considered that the overrun

cost of rework can be mitigated or even eliminated by improving management and adopting specific measures.

4. The tracking and measurement of the impact of rework of construction project was conducted in a static state, which means that the measurement revealed the severity of reworkin certain trades during specific period. However, further questions required answers in order to facilitate improvements in a general rework reduction program model:
   - How much of the rework and its cost could be reduced through the application of a specific rework reduction program in construction management.
   - How significantly affected to related corrective actions, for the reduction in rework

To answer these questions, this research conducted a case study in a current facility maintenance and modification construction project over a considerable period of time. Variations in the influence of rework over the whole project timeline were observed with the goal of revealing whether the new rework program applied to construction management could have a significant positive effect on the reduction of the rework and its impact on project performance.

For the purpose of this study, the case chosen needed to have the following features:

- The project has a timeline that is long enough to provide sufficient data to enable an effective comparison and trend analysis of the rework
- The adverse impact of rework on project performance is significant enough to have merited the attention of the project management
- An adequate amount of data can be accumulated over a long enough period to permit meaningful quantitative analysis.

3.0Research Methodology

3.1 Introduction

The study sought to determine the causes of rework occurrences in the design and execution stage of building projects and best practices to minimize its effects on samedue to organizational management practices, and project management practices.

The purpose of this chapter was to identify and clarify rework in buildingconstruction projects and to develop rework reduction methodologies.

On achieving this, rather than developing a questionnaire survey that sought respondents' general opinion about rework, this research was asked respondents to select a recently completed building projects most familiar to them and to subsequently answer questions about the perceived causes of rework associated with the environment and project management practices implemented.

Work categories comprised 10 of which were mostly common in building constructions identified to conduct this research both in identifying factors affecting rework and proposing best practices and developing checklists to minimize rework in the said trades.

Respondents, who were selected for the research, closely involved to the construction stage and actively participated to the projects representing either contractors' organization or project management organization.

Basically, there were three elements considered to conclude interviews successfully when drafting the interviewer guide: (1) the respondents easily understand the core of the research, (2) minimum time to allocate for interviews and (3) minimum questions referred to respondents at the time of interviews.

On this basis, 4 questions were prepared to pose problem definition and all objectives of the research and supportive documents along with possible causes and best practices which were identified on the literature review, also prepared to facilitate the interview.

The system used in the analysis for identifying the root causes of rework was based on the categories of rework developed by the performing groups of the project. Main factors identified and categorized accordingly.

This type of procedure was selected to take precise information and face to face interaction would avoid laziness and reluctance when the details were questioned.

This chapter is divided into five sections to discuss methodologies, the first section will describe the proposed field rework definition, the second section will explain elements in the interviewer schedule, the third section will show what types of projects are selected, who are the interviewees and how they are selected, the fourth section will explain how the data were collected, and the fifth section will describe the methodology for data analysis.

3.2Proposed Field Rework Definition

For the purpose of detailing the research in this paper, rework is defined as “the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time” (Love, 2002).

The study in the areas of the design and construction management practices is elaborated to interviewees along with the objectives of the research, clearly indicative scope, and extent which clearly details what is and what is not considered rework from an industry-wide perspective.

These exclusions in below, explain the scope and extent of the research which needs to open up broad view to interviewees during the time of interview.

- Project scope changes that are not disrupted the flow of construction activities
- Design changes or errors that do not affect field construction activities.
- Off-site fabricator errors that are not carried out under the supervision of site staff
- Rework due to additional or missing items of designers or contractor are considered under the relevant factors

Also, the research is limited up to five storeyed buildings projects in the nature of extensions, renovation and brand-new which are in the state of recently completed.

3.3Interviewer Schedule/Guide

An interview questionnaire is developed to achieve the objectives presented in this research paper, i.e. to identify factors affecting rework, to propose best practices to minimize rework, and to develop checklist to minimize rework for selected trades. A list of questions for interview is developed to examine the influence of design and construction management practices on rework in all selected trades in building construction and these data are collected in line with the relevant trades for rework incidences. Also, an interview is included questions to present best practices related data to minimize rework or improve project performance in building construction. An interview schedule is prepared in a form of simple questions to cover 10 main selected trades in rework occurrences and they are setting out, Random Rubble Masonry, Brick Work, Reinforced Cement Concrete, Plaster Work, Tile Work, Waterproofing, Painting, Carpentry Work, Aluminum and Glass Work.

The interview schedule (Appendix A) is included ten work categories which are common in the building constructions.Following questions were mooted to the respondents during the interview,

1. For each selected trade, what are the causes for rework,“indicate the causes of rework in the relevant row”.
2. What best practices are proposed to minimize rework for each work category?
3. What should be included as checklist indicators to minimize rework for each work category?
4. Indicate any impact of rework on project performance or productivity other than cost and time.

In addition to above initiation, questions to initiate dialogue with respondent, other supporting questions which are required to ascertain all the possible reasons behind rework occurrences and helped to remind them during the construction stage of project, presented to dig and find all real causes of rework. The respondents are being questioned with the help of these questions in a row as required toare: how it happens, who involves for the change, how the contractor responses in first occasion, who confirmed the change, who signed for the variation order, how frequency of rework occurrences and also rework due to insufficient and incompetent supervision, poor workmanship, selection of improper subcontractor, lack of coordination, improper work protection, wrong and defective material usage, and deviations from drawings.

Respondent amidst in deep in concerning answering responses to my questions tactfully, questions 2 and 3 use to take their best practices or checklist indicators which can be used to minimize rework in similar passion.

Questions 4 is used to ascertain other impact of rework to the project performances

And the interviewees were asked questions at the interview to explain more about how the rework causes caused rework in each work category, and the circumstances of the execution of each work category.

The interview schedule is attached with a list of possible causes of rework (Appendix A) under the category of design causes, construction causes, client causes, site management causes, and subcontractor causes and a list of possible best practices to minimize rework under the category of project scope, contract documentation, procurement strategy, project communications, design management (Appendix B) for the purpose of achieving realistic result during the interview time. Also, they will use to facilitate for interviewer to explain and get all possible causes and best practices.

3.4 Selection of Interviewees and Projects

It is necessary to identify engineers in the relevant discipline who were working as project managers, site managers, project engineers, construction engineers, and site engineers etc in the construction related organizations and selected to the initial discussion pertaining to the research. Andthis identification of engineers was carried out through friends and with the help of supportive organizations.Thereafter, they werecontacted over the phone and briefed about myself and the research. Also, they were queried about building construction experiences whichwere recently completed up to five stories.

After this initial briefing process, potential participants were identified on their appropriateness for the research and willingness for support. All engineers selected were initially listed with their names, contact number, and emails.

Reserving time and place to conduct discussionswas done well in advance of the actual date of the interview sessions. Finding a location which was tried to find the most convenient and accessible location for the participants and interviewer and allocating a time which was set to contact potential participants with the necessary logistical information.

Subsequent reminder was set to the relevant respondent just before the interview date along with time and venue.

Initial list was updated at the end of the interview and potential respondent list updated accordingly.

3.5 Data Collection Method

As agreed upon with the respondent, interview was held at the particular time and venue and conversed few minutes amicably and briefed about the research, objectives and data collection method. Expected conclusions also highlighted to the interviewee to grasp the importance of this research outcome to the construction industry covering the pre-construction and post construction stages.

Meantime, general information of the interviewer was recorded under the first section of interview schedule and it includes name, designation and contract information of the interviewee and the date of interview. Also, basic information regarding the projects which was completed recently, recorded with name of the project, project location and project completion date and name of the contractor was also recorded.

Number of floors and floor area in the relevant building were recorded for the purpose of describing the gravity of the project and nature of the building were also recorded to ascertain whether the building was brand-new, renovation or expansion pertaining to the researchcharacteristics.

In line with interview schedule, first question in case of setting out was mooted to the interviewee and asked "how it happens", "who involves for this change", and other questions which helped to remind the project as well as the background of rework occurrence of setting out. Thus, all possible causes highlighted by the respondent were recorded.

Similarly, all work categories in the interviewer guide were opened up to the respondent and recorded all possible causes in the relevant work. The questions, how it happens, who involves for change, how the contractor responses in first occasion, who confirms the change, who signs for the variation order, the frequency of rework occurrences, rework due to insufficient and incompetent supervision, rework due to poor workmanship, rework due to selection of improper subcontractor, rework due to lack of coordination, rework due to improper work protection, rework due to wrong and defective material usage, and rework due to deviations from drawings, were raised to the respondent as its appropriateness to the situations and facilitated and helped the respondents to remind the whole picture of the project and the circumstances of the execution of each work category.

So, next two questions what best practices were proposed to minimize rework for each work category and what steps should be included as checklist indicators to minimize rework for the category of setting out was also mooted to the interviewee and recorded possible best practices or checklist indicators for the administration of best practices to minimize rework.

Similarly, other work categories such as RRM, Brickwork, RCC, Plastering, Tile work, Waterproofing, Carpentry, Aluminum Glass work, Painting were considered and any best practices to rework occurrences were recorded.

Next question "indicate any impact of rework on project performance or productivity other than cost and time" was also mooted to the interviewee to ascertain any other pattern of impact to the project performance.

3.6 Data Analysis Method

Proposed Rework Classification System

The classification system proposed in this research for categorizing causes of rework is based on the Three Factor Classification System which was developed having explored all potential and actual causes of rework, especially the Cause and Effect diagram developed by Love at all in 1997 and Fishbone Classification System developed by Construction Owners Association of Alberta(Fayek et all) in 2003.Also,it was helped to developseveral other researches such as causes of rework were categorized based on the initiator of the cause done by Love et all in 2003and rework classification structure was proposed by Di Zhang in 2009.The Three Factor Classification System consists of three broad areas based on the rework performing group in the construction projects. They are,

- Design and Engineering Factors
- Client Factors
- Site Management Factors

Further, analysis of these main factors with the awareness of previous research, it was identified following possible causes to Design and Engineering Factor and Client Factors.

- Changes in Design to site condition
- Errors or omissions in drawings and specifications
- Lack of coordination among design consultants
- Changes made at the request of end user/regulatory bodies
- Insufficient time to prepare contract documentation
- Inadequate client brief to prepare detailed documentation

Client Factors identified contained these causes,

- Lack of experience and knowledge of DC process
- Lack of funding allocation for site investigations
- Inadequate client participation at the design stage
- Low fees payment for preparing contract documentation
- Changes made by client at the construction stage

Site Management Factors further looks to in its all areas with the help of previous research especially indicated in the above.

- Planning and Scheduling
- Leadership and Communication
- Knowledge and Supervision
- Material and Equipment use

Planning and Scheduling

- Poor planning and scheduling of construction procedures
- Poor application of realistic work procedures/construction methods
- Poor planning of workload
- Ineffective use of quality management practices
- Ineffective use of IT

Leadership and Communication

- Lack of standard communication procedures
- Misalignment of expectations from contractor, subcontractor
- Unclear instructions to workers

Knowledge and Supervision

- Incomplete supervision due to lack of technical knowledge
- Poor workmanship
- Failure to provide protection to the works
- Insufficient managerial and supervisory skills
- Low labour skill level

Material and Equipment use

- Non-compliance with specification
- Inadequate material/equipment protection for delivery
- Equipment and tools not sufficiently advanced
- Use of substandard material/wrong material

Root causes for rework of each work category were studied and understood thoroughly and categorized into relevant causes under its corresponding main factors described as above. In doing for this purpose, the matrix prepared by means of spread sheet that is used to elaborate carefully for all main and secondary causes along with its root causes with the broad classification under the three factor classification system shown in Fig: 4.1.

Rework causes section of each Interview Guide are reviewed thoroughly and each cause is classified with the help of the matrix described above and marked them in the relevant column of work category. It has some difficulties to classify causes when the different terms are met in similar rework cases; they are justified to the closest reasons in the classification system. In some cases, there are several root causes that lead to rework incidence and they are apportioning to the resulting rework item in the matrix. It is important to remember that every cause is treated equally when compared. In this manner, matrix is completed with causes of all interview guides.

Then, graphical representation is performed with the number of causes of each factor to the total number of rework occurrences. Similarly, secondary factors also represented graphically on above basis.

Proposed System for Best Practices

The classification system in below proposed for best practices to minimize rework is based on the facts found previous researches such as Love, Peter E.D. and Smith, Jim in 2003 and Zhang, Di and Haas, Carl T. in 2011along with responses received from respondents. The responses under the best practices/checklist indicators in the Interview Guide carefully studied and categorized into following three areas covering whole construction field. They are,

1. Best Practices proposed as contractual requirements
2. Best Practices proposed in design stage
3. Best Practices proposed in construction stage

These three areas were also identified as key areas affected to the rework when considering all responses given at the time of interview. All the responses could be able to categorize into the above areas and accordingly develop checklist indicators for some selected trades considering whole process of its complete construction highlighting its planning stage and construction stage. In the planning stage, checks for the approvals of quality of materials and for the approvals of drawings are considered, and in the construction stage, whole process is considered including workflow checks.

3.7 Reasons for Selection of Methodology

The interview is an alternative method of collecting survey data. Rather than asking respondents to fill out surveys that sought respondents' general opinions about rework, interviewers ask questions orally and record respondent's answers. This type of survey generally decreases the number of "do not know" and "no answer" responses, compared with other available methods. Interviewer also provides a guard against confusing questions. If a respondent has misunderstood a question, the interviewer can clarify, thereby, obtaining relevant responses. As noted previously, personal interviews are a good way to gather correct information from respondents rather than other methods because respondents actually concentrate for the discussion and opportunities to give lazy and poor answers are rare.

Some advantages of the personal interviews are:

- *Flexibility*: allows flexibility in the questioning process and allows the interviewer to clarify terms that are unclear.

- *Control of the interview situation*: Can ensure that the interview is conducted in private, and respondents do not have the opportunity to consult one another before giving their answers.
- *High response rate*: Respondents who would not normally respond to fill out surveys and other types of questionnaires will often respond to a request for a personal interview.
- *Face to face interaction*: help researchers to obtain complete and precise information.
- *The opportunity feedback*: personal interview allows for feedback. Reluctant to provide sensitive information about project may be reassured by the interviewer that the answer is strictly confidential.
- *High participation*: While some people are reluctant to participate in a survey, the presence of an interviewer generally increases the percentage of people willing to complete the interview. Respondents are generally not required to do any reading or writing - all they have to do is talk. Most people enjoy sharing information and insights with friendly and sympathetic interviewers.

Some of the disadvantages are:

- *Time wasting*: While the venue is a working place, respondents are busy and come up with excuses in presenting urgent works, sometimes.
- *Higher cost*: Cost are involved in the travel and time required to conduct interviews.
- *Interviewer bias*: The advantage of flexibility leaves room for the interviewer's personal influence and bias, making an interview subject to interviewer bias.
- *Lack of anonymity*: Often the interviewer knows all or many of the respondents. Respondents may feel threatened or intimidated by the interviewer, especially if a respondent is sensitive to the topic or to some of the questions.
- Interviewer's tone of voice and the interviewer's appearance may influence the respondent's answer.
- When a person selected to be in the sample can be contacted on the first visit, a systematic procedure is normally initiated to callback at another time. Callbacks or attempt to re contact individuals selected for the sample, are major means of reducing nonresponsive error.

4.0 Analysis and Results

4.1 Analysis and Results

The data for this study are the results of 35 interviews administered with 23 respondents who are working to the side of contractors and consultants. 60% responded representing contractors and 40% responded representing consultants. A root causes analysis of the 114 field rework incidences collected during the study from all 35 projects performed according to the Three Factor Classification System. Total rework causes occurrences is 320 due to some rework incidences have several causes. Table 4.1 shows the field rework summary where all rework incidences are recorded with their respective causes.

4.2 Analysis to identify factors affecting rework

The Three Factor Classification System used in the analysis for identifying the root causes of rework is based on the categories of rework developed by the performing groups of the project. The objective of this approach is to identify root causes that contribute to field rework and to categorize same accordingly for the purpose of minimizing and preventing their occurrences in the real construction works.

According to this classification system and by means of matrix shown in above table, all causesfor rework collected from recently completed projects are classified into the classification system and they are categorized accordingly intoits categories under main factors i.e. Design and Engineering Factors, Client Factors and Site Management Factors and further classify site management factors. These causes are proportionately represented the total rework occurrences.

Figure 4.1 illustrate the percent contribution of main rework factors based on rework cause occurrences.

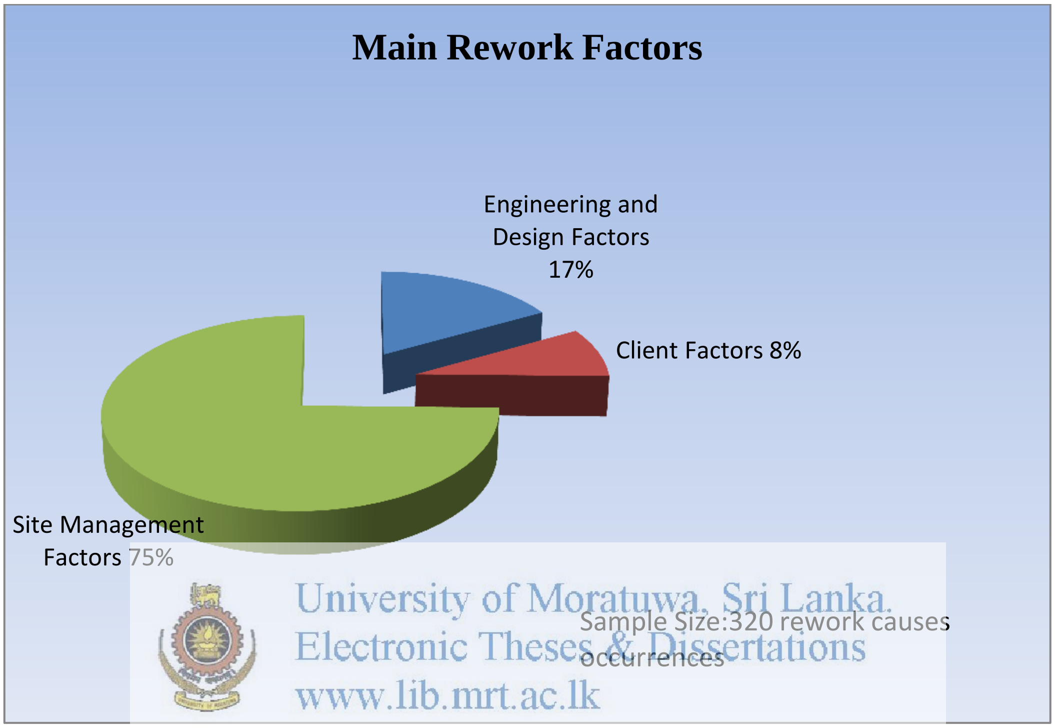

Figure 4.1: Analysis of Main Factors for Rework

"Site Management Factors" is the main contributory factor that most significantly affected to rework with 75%."Engineering and Design Factor" is affected with 17%."Client Factor makes relatively low contribution to rework accounting for 8% of the rework causes.

The relative contribution analysis for Site Management Factors is based on the contribution of each rework root cause to the overall rework cause occurrences (320).Figure 4.2 shows secondary level analysis of site management causes which includes knowledge and supervision causes, material and equipment use, planning and scheduling and leadership and communication.

“Knowledge and Supervision” and “Material and Equipment use” contributed to the rework under the categorization of site management factors are 53.75% and 11.88% respectively.”Planning and Scheduling” contributes to the rework under this main factor is 6.25% and “Leadership and Communication” contributes rather less significance to the rework is 2.81%.

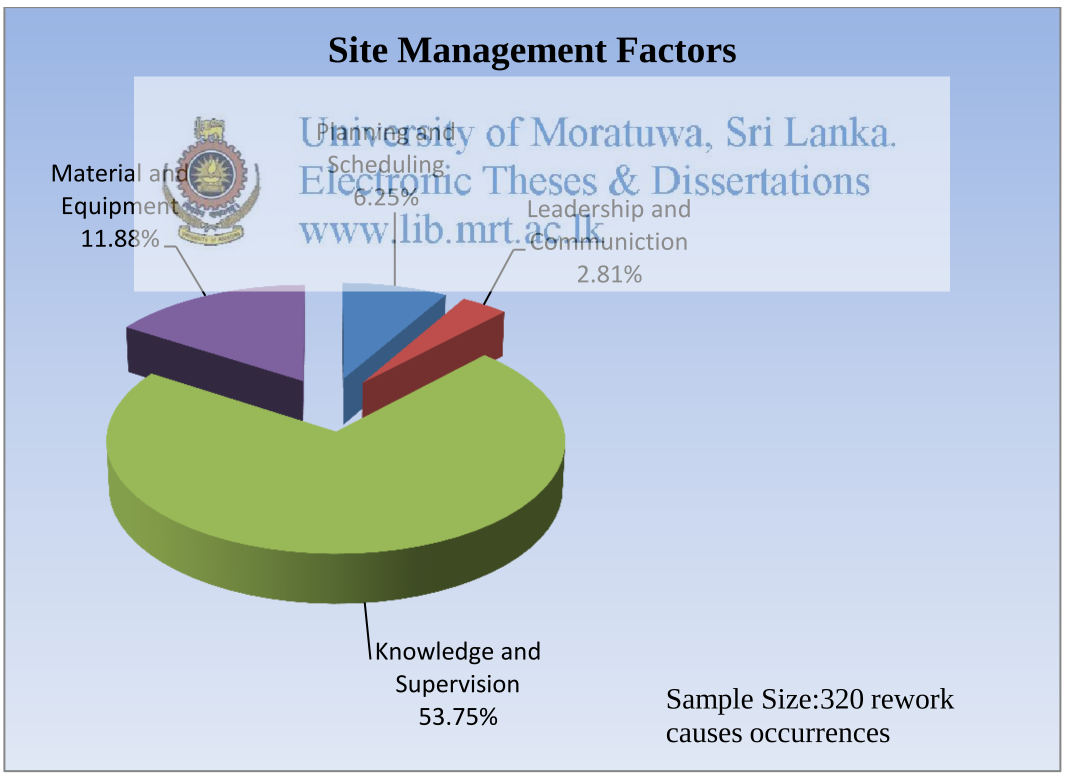

Figure 4.2: Analysisof Site Management Factors

A similar approach is taken to analyze main factorsintofurther categorization based on the sample data obtained from the total rework incidences. In the analysis of design and engineering factors, ”Changes in Design” in respect to the on-site conditions and client request is significantly found to contribute to rework is 10.63%.Certain client requests also considered for this category because these requests mainly due to irresponsible discipline of design team members. This reveals that design team members work with their scope of work elegantly but it is very poorly coordinated themselves as well as client. In the result of happening this, excessive “Errors and Omissions in Drawings and Specification” and “Lack of Coordination among Design Team” contribute to rework by 3.13% and 1.88% respectively.”Changes made at the request of End-User” is affected to rework is 1.25%. This survey was conducted on the site management staff representing both contractors and project management organizations, so insufficient time to prepare contract documentation and inadequate client brief to prepare contract documentation given no response as they were not aware of occurrences at this juncture.

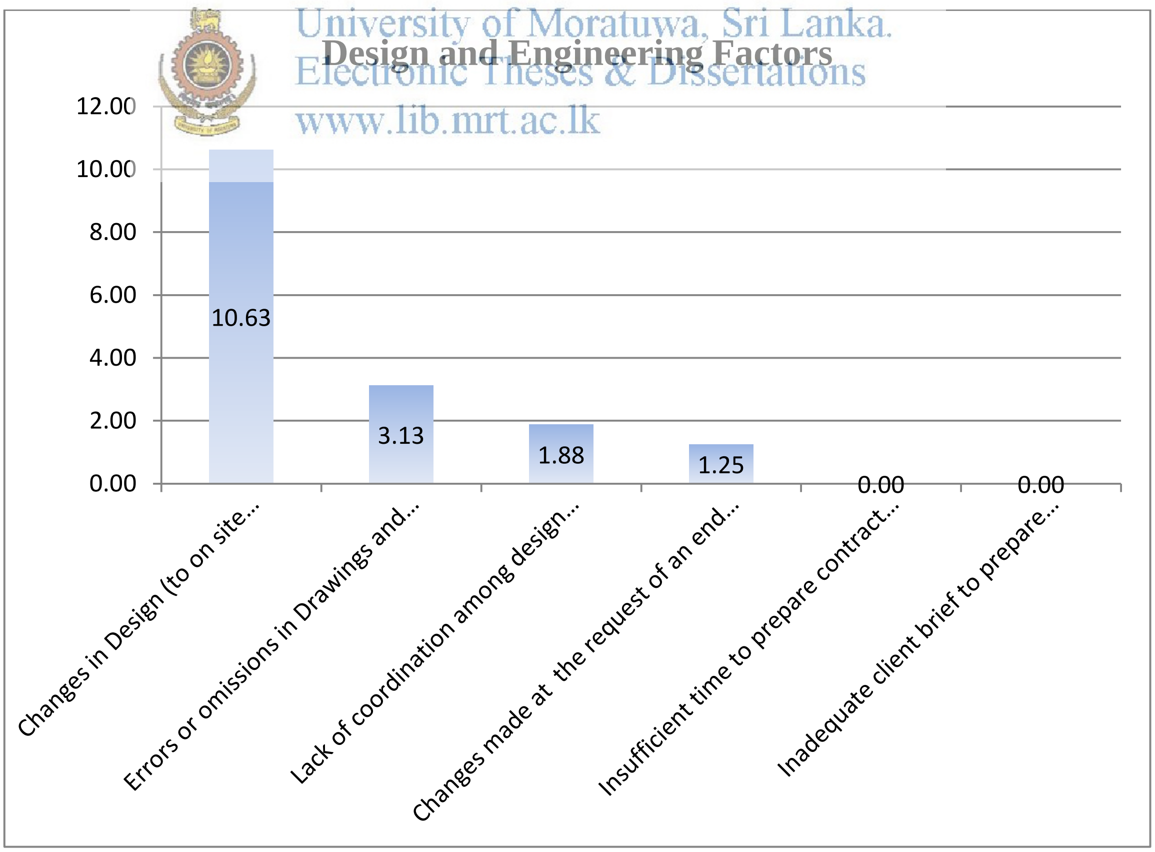

Figure 4.3: Analysisof Design and Engineering Factors

Referring to the figure 4.4 of those sub categories of client factors "Inadequate Client Participation at the design stage" and "Changes made by the client at the construction stage" contributed 3.44% and 5%. Remaining other factors are not contributed mainly due to survey conducted by site management personnel.

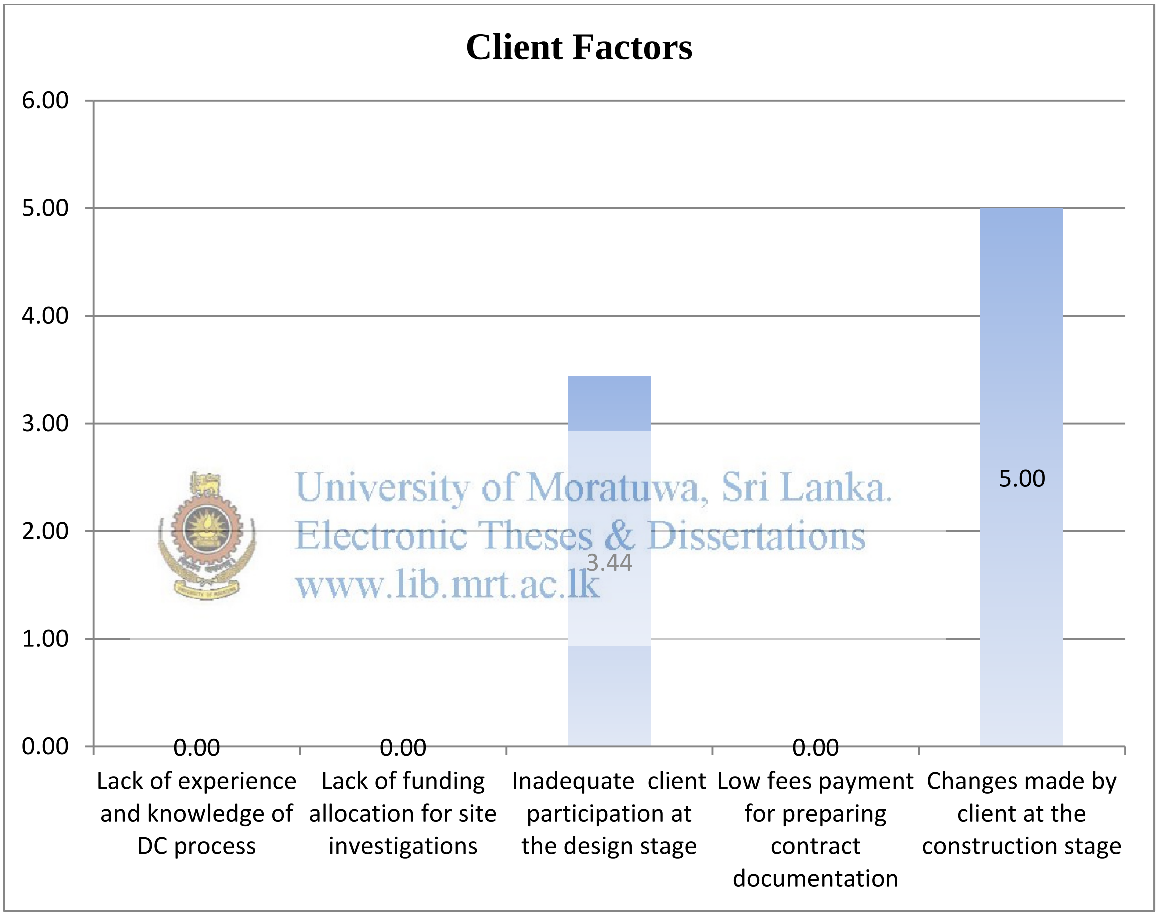

Figure 4.4: Analysis of Client Factors

As shown in Figure: 4.5, knowledge and supervision under the category of site management factor is significant as described above. Further analysis of knowledge and supervision factors demonstrates the root causes of rework which are contributed to rework as incompetent supervision due to lack of technical knowledge is 5.31%, poor workmanship is 17.5%, failure to provide protection to the works is 9.38% , insufficient management and supervisory staff is 15.94% , and low labour skills level is 5.63%.

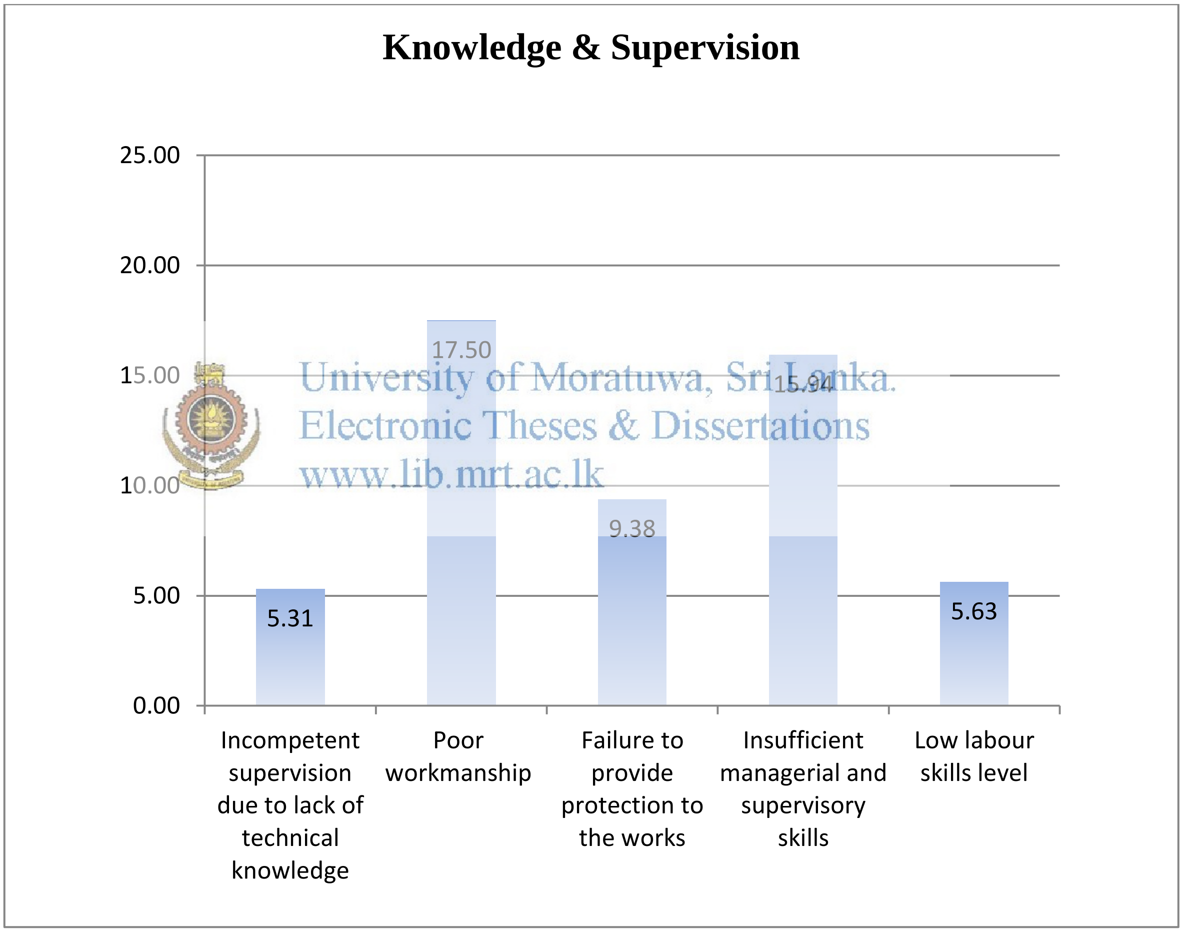

Figure 4.5: Analysis of Knowledge and Supervision Causes

Poor workmanship as a rework cause significantly affected 10 work categories displaying its frequencies on different work categories in Table: 4.1. Poor workmanship is often happening to plaster work, tile work, brick work and carpentry works.

The average of frequencies of the poor workmanship is a reflection of the skills and experiences of the workers. For instance, the skills and experiences of the workers of the plaster work, tile work, brick work and carpentry work are very low which means this cause is happening often for these work categories. The interviewees provided information on the circumstances and some examples of poor workmanship on RRM, RCC, Painting, Aluminum and Glass work, and Waterproofing.

Insufficient management and supervisory staff is a direct rework cause. As shown in Table 4.2, as a rework cause affected to all work categories with different frequencies. It was happening often in brick work, RCC, plaster work, tile work, waterproofing, painting, and aluminum and glass work.

The interview revealed that information on this issue mainly due to workers were assigned to the work categories and carried them out in their own passion without involvement of the management and supervisory staff. This is often happening with labour subcontractor method.

As shown in Figure: 4.6, material and equipment use under the category of site management factor is affected as described above. Further analysis of material and equipment use causes demonstrates the root causes of rework which are contributed to rework as non-compliance with specification is 3.13%, inadequate and material/equipment protection for delivery is 1.25%, equipment and tools not sufficiently advanced is 0.63%, and use of substandard material is 6.88%.

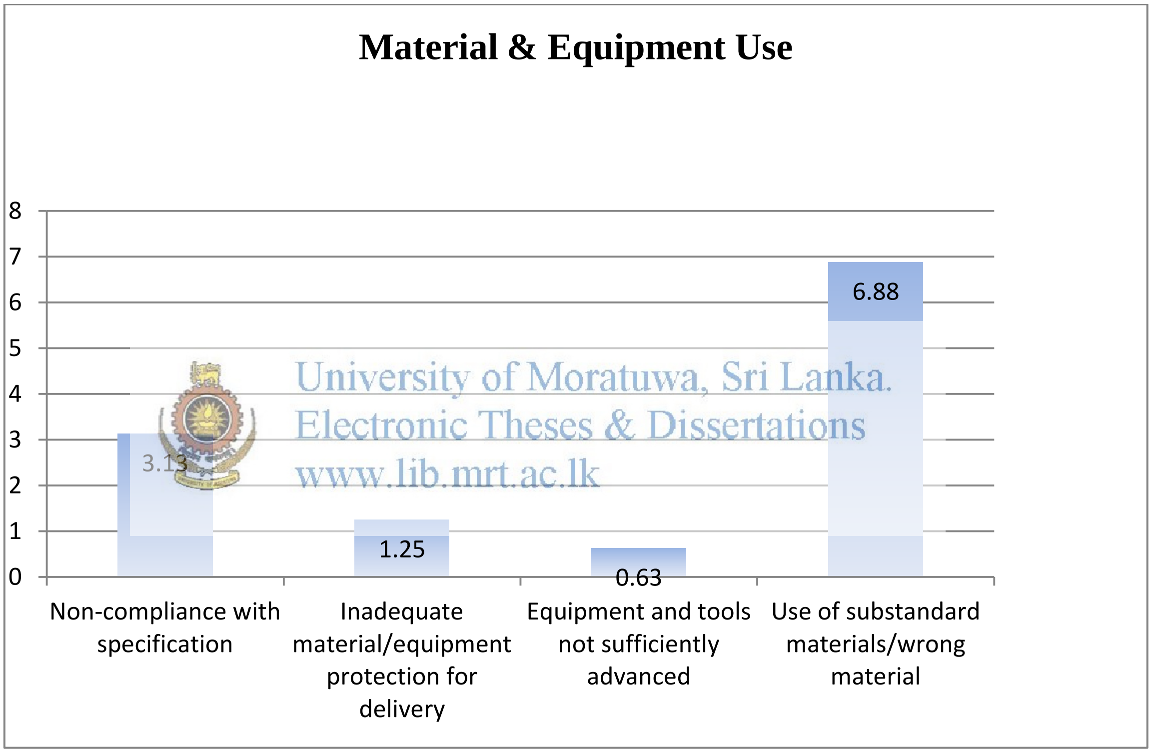

Figure 4.6: Analysis of Material and Equipment Use Causes

As shown in Table 4.1, non-compliance with specification and use of wrong material are affected in a similar capacity for work categories such as RCC and carpentry work. No significant occurrences in other work categories were recorded in inadequate material/equipment protection for delivery and equipment and tools not sufficiently advanced.

As shown in Figure: 4.7, planning and scheduling under the category of site management factor is affected as described above. Further analysis of its causes demonstrates the root causes of rework which are contributed to rework as poor planning and scheduling of construction resources is 0.94%, poor application of realistic work procedure is 1.25%, poor planning of workload is 1.25%, and ineffective use of quality management practices is 2.81%.

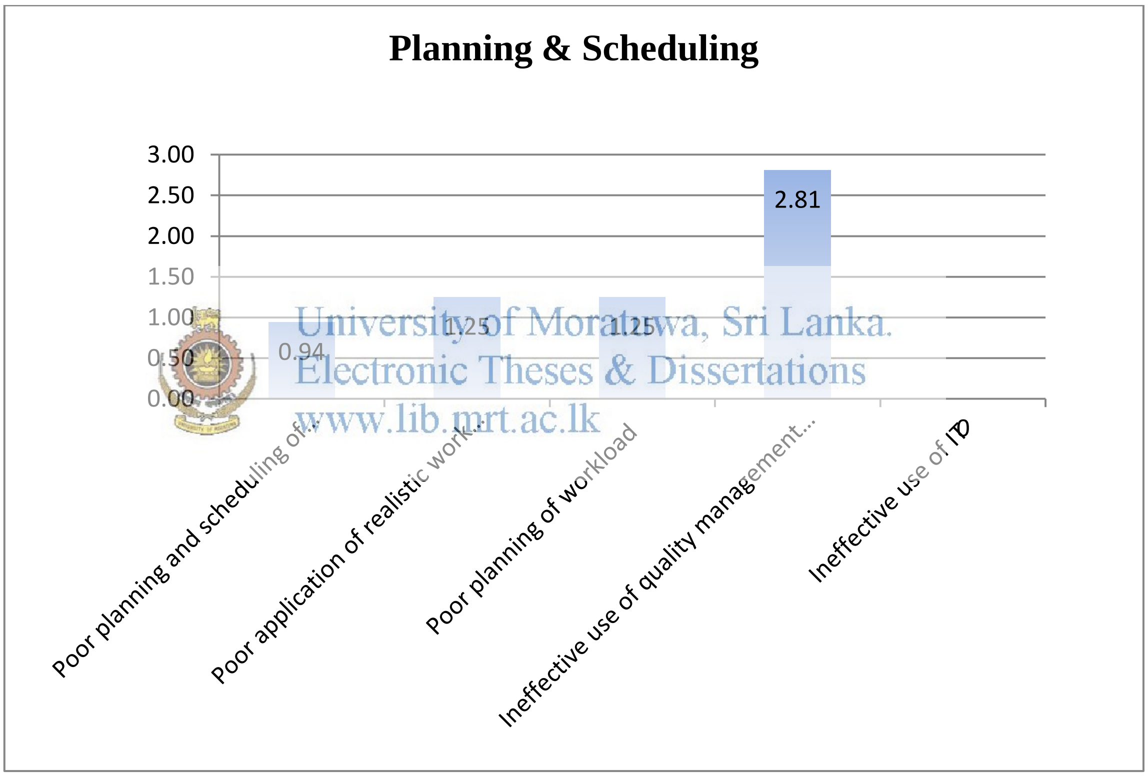

Figure 4.7: Analysis of Planning and Scheduling Causes

As shown in Table 4.1, ineffective use of quality management practices is affected for almost all work categories in a similar manner. Poor application of realistic work procedure is affected to the rework in the setting out and painting while poor planning of workload is affected to the rework in the setting out, RCC, plaster and aluminum and glass work almost in similar capacity. Poor planning and scheduling of construction resources is reported to rework only in setting out work.

As shown in Figure: 4.8, leadership and communication under the category of site management factor is affected as described above. Further analysis of its causes demonstrates the root causes of rework which are contributed to rework as lack of standard communication procedures is 1.25%, misalignment of expectation of contractors and sub-contractors is 0.31%, unclear instructions to workers is 1.25%.

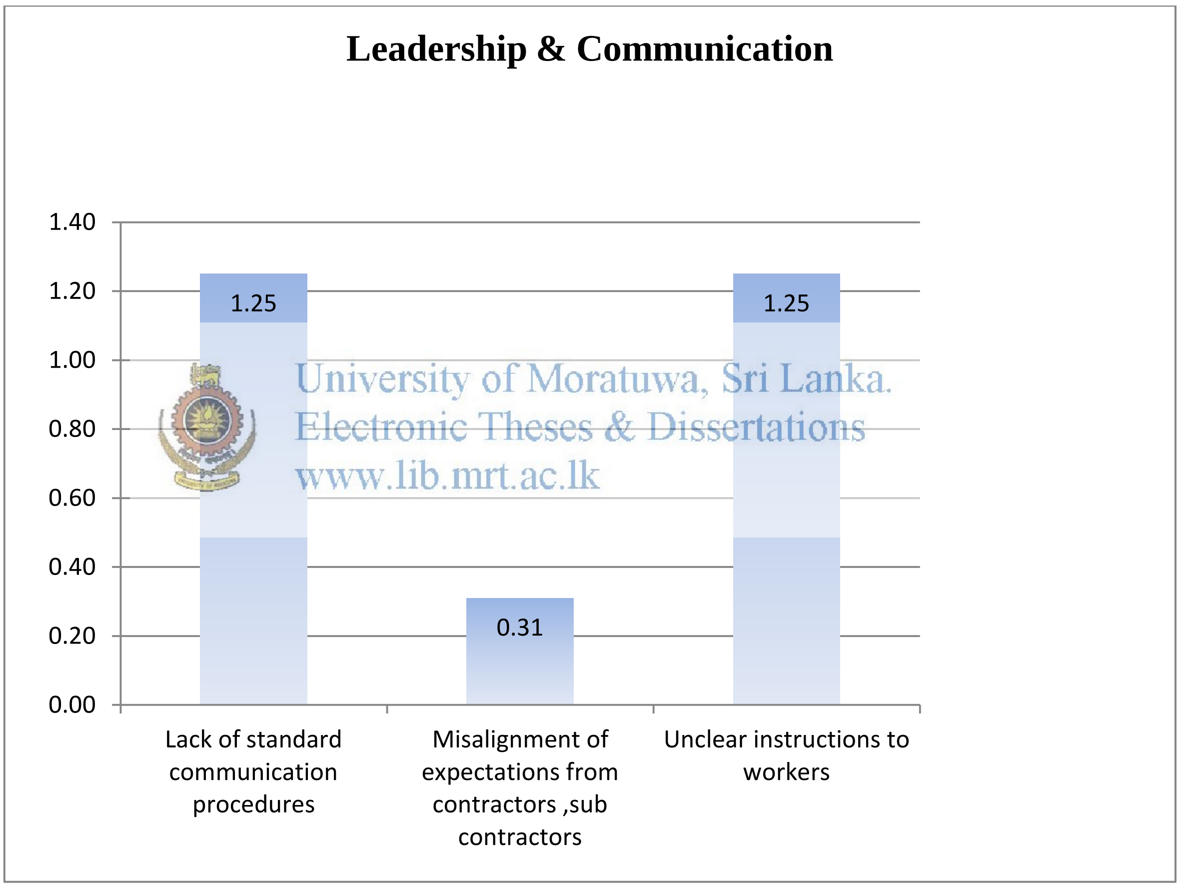

Figure 4.8: Analysis ofLeadership and Communication Causes

As shown in Table 4.1, all above causes are affected to the rework for work categories such as setting out work, RCC, painting and aluminum and glass work in similar frequencies.

4.3Analysis to proposeBest Practices to Minimize Rework

For the purpose of identifying best practices categories, proposed system developed exploring previous research is used to identify the best practices from data which were collected from the interviews. Also, best practicesis defined as “a process or method leads to enhance project performance when executed effectively”.

BP proposed as contractual requirements

BP proposed in design stage

BP proposed in construction stage

The objective of this approach is to develop an industry best practice for effectively measuring and quantifying construction field rework so as to improve the performance culture in the building construction sector and other procedures and practices that need to be adhered in the design and construction stages for the same purpose.

Best Practices to minimize rework

1. BP as contractual requirements
    i. Standard definition for rework
    ii. Standard measurement method for rework
    iii. Standard classification system for rework
2. BP in design stage
    i. Project scope definition is re-evaluated prior to tendering
    ii. Disciplined approach to decision making is conducted by client
    iii. Client participation for meetings is performed
    iv. Guidelines of end-user to be followed
    v. Client’s needs and practices are communicated to the project team
    vi. Roles and responsibilities of the project team are defined in terms of discipline
    vii. Communication lines to be followed
    viii. Contract documentation is cross-checked and enhanced

ix. Specifications for the quality requirements are clearly mentioned
x. Details in drawings is of a high standard
xi. Descriptions in BOQ are completed
xii. Design reviews and verifications are conducted
xiii. Design and specification are produced to real site conditions

3. BP in construction stage
   i. Any change/error/omission identified is immediately reported and acted upon
   ii. Project quality management systems are established and followed
   iii. Request for information is raised in a timely manner
   iv. Working procedures are followed and supervised
   v. Labourers specialty is identified very early and employed accordingly
   vi. Well experienced staff employed
   vii. Adequate supervision is employed
   viii. Well experienced staff employed
   ix. Awareness of details and specifications by project staff are studied at least two steps in advance
   x. Coordination and communication among site staff are conducted
   xi. Supervisors are employed as per work category
   xii. Site documentation

4.4Discussion to Best Practices to Minimize Rework

In project-based transactions, anyoccurrences of rework are mainly considered as unnecessary or non-value adding activities. The observations from the rework research identified that there is no systematic approach specifically followed for monitoring rework occurrences and their impacts in the building construction sector. In addition, even though there are various types of checklists, procedures, and measures implemented in the construction industry, those are no effective enough and no contractual ties to find a lasting solution for this. Also, at present, compensable recoveries from other parties through contractual claims, ad hoc measure to enhance the sustainability and profitability in contractor organization, and risk management mechanism like measures are being implemented in the construction on the agreed consensus among parties.

It is obvious that the rework impacts in the aspect of performance and productivity need to be controlled and mitigated by adopting various measures such as through contract management, quality management, project management and value management. A systematic mechanism is, thus, essential for effectively tackling the rework related inefficiencies, losses and most of the resulting ripples impacts. To approach for this as effective management measures, best practices discussed under the above three areas can be implemented through contractual, quality management, risk management aspects.

4.5Analysis to Develop Checklists to Minimize Rework for Selected Trades

As an actual practice, several Checklists for Brick Work, Floor Tile Laying, Plastering and CeilingWorks are discussed herewith for the purpose of minimizing rework in the construction projects which illustrates in the Table 4.2, 4.3, 4.4and 4.5 respectively.

5.0 Conclusions and Recommendations

5.1Summary

Field rework is identified as a problem by owners, engineers and contractors, and importance of reduction of rework results reduction of cost and improvement in achieving schedule milestones, and improves predictability of project outcomes. The undesired outcomes pertaining to rework can be substantially reduced through developing of adequate awareness as well as structured systems for rework management. In order for the construction industry to benefit from this research, conclusions and recommendations, especially the implementing best practices must be used to enhance performance and productivity with the updated data in building construction.

5.2 Conclusion

This research is covered the identification and classification of the causes of rework, proposing best practices, checklists for certain trades. In order to examine above objectives, the study has been able to explore qualitative rework data of recently completed building projects for the selected trades, and respondents' views in terms of improving project performance and productivity. The following conclusions are drawn from the analysis of causes of rework occurrences of the selected projects.

Based on the classification system used in the analysis, site management factor is contributed significantly to the occurrences of rework in the building construction sector other than the Design and Engineering factor and Client factor. In the further analysis of site management factor, knowledge and supervision contributes to rework with 53.75% while poor workmanship and insufficient management and supervisory skills contribute to same 17.5% and 15.95% respectively. Apparently, an increased emphasis in respect of the site management factors is required to avoid and improve project performances. There are some conclusions disclosed from the study regarding the severity of rework on work categories such as setting out, brick work, plastering concrete, and tile work.

Design and Engineering factor contributed to rework occurrence to 17% is the other major factor. Changes in design occurred mainly due to initial designs are not done to the site conditions, lack of client's awareness about critical features and scope of the work, and errors and omissions in the drawings and specifications. As far as these root causes are concerned, all could be averted and minimized through having the closest link among stakeholders and effective communication.

Following are proposed by respondent to avert or minimize rework occurrences in all aspects as it is identified as a problem and affected to schedule and cost overrun, meeting schedule milestones, predictable outcomes, and quality of products.

- Rework data tracking is contractually required
- Qualified personnel to monitor this process
- Establish a standard definition for rework
- Establish a standard measurement method
- Establish a standard classification system

Also, research has suggested that the quality of site supervision, represented by the supervisions' level of experience gained from formal, has strongly affected to the rework in the projects.

This research argued that the site supervision has a vital role in reducing the amount of rework in the construction industry. The supervision needs to be employed to the required extent so as to produce skillful environment and identify capability of skilled labour and also carry on with work accordingly.

However, there exist a number of challenges that researchers have regularly come across when examining rework reduction and elimination, which are indicative of cultural and organizational changes that must be overcome successfully to deal with rework.

Better understanding of causes of rework will assist project managers to identify the best methods to improve the performance of contractors to minimize or eliminate rework. Both supervisor skills and labour skills should be considered as a key point in carrying out construction projects.

Prices, financial status, environmental management, quality management, safety management, project teams, and skilled labour become vital issues and they are carefully assessed when awarding jobs to contractor companies. In this context, labour productivity performance plays a key role in determining the financial success of a project.

The positive attitude needs to be dealt with in order to resolve the rework issue that the solution to rework is known and that the solution is straight forward. Contractors sometimes have difficulty to acknowledge that rework exists on a project. Rework causes and solutions need to be identified on a non-emotional level.

It has concluded that to improve project performance and to reduce the menace of rework costs, there is need for consensus to be reached on a workable mechanism to bring together the client and the contractor to minimize change orders and introduction of additional works during construction phase.

5.3 Recommendations

The following measures to reduce rework in the construction projects and improve performance and productivity in applying best practices are recommended.

- When using multiple contractors as a procurement method, it is recommended to use a construction management company to manage the whole process from the inception of the project.
- Project consultants must review and revise the contractor's submittals such as material submittals, quality control and quality assurance plans, submittals schedule.
- When practical, the contractor should make a mock up sample for major and repeated project elements; it should be inspected by the quality control personnel and approved by the owner representative, consultant before proceeding with works.

- Owners, consultants, and contractor's inspectors should inspect each work phase before proceeding to the subsequent phases.
- The project owner, consultant, contractors, and sub-contractors should ascertain that project personnel possess the required skills and experience. Training programs should be used when appropriate.
- The owner should approve his project contractor's organization chart and qualification of key project personnel before the commencement of the works to ascertain their adequacy and competency.
- Representatives of the project should check regularly the presence of the entire contractor's and the subcontractor's staff in site.
- To reduce rework caused by subcontractor selection, contractor should consider the following in the selection of his subcontractors and the client representatives also should approve this selection:
    - Subcontractor's performance in recently completed projects
    - Subcontractor's staff qualifications, experience and skills

- The usage of wrong material in construction projects can be avoided by checking the delivered material to the site more than once, by different entities, such as bythe contractor's supervisor, by the store keeper, then by the field inspector before installation.
- Defective material whichmay cause rework could be reduced in construction industry by implementing quality assurance measures to enhance the quality when delivered to the site by the above.
- The improper work sequencing as a rework cause can be reduced by frequent checking and updating the project time schedule.
- To reduce errors and omissions happenings in contract drawings and specifications in construction projects the following recommendations should be followed:
    - Each design phase should be checked by the client's representative and approved before proceeding to the next phase.
    - Contract drawings should be checked and approved by contractor before commencing shop drawings production
    - Shop drawings should be checked by site consultant engineers for approval before starting construction.
    - To reduce deviations from drawings it is recommended to inspect works and check its compliance with drawings frequently by contractor's supervisor at field inspection

5.4 Recommendation for future studies

More research is still needed so that practical solutions can be produced within a contractual framework in order to find strategies to zero the rework for the purpose of improving construction performance and productivity and reducing rework resulting a reduction of cost and achieving the scheduled milestones. Following points are mooted as future studies in this respect.

- A method is required to track actual amount of rework as soon as it happens at site.
- Impacts of rework occurrences on the part of contractor and client needs to be studied in separate formats.
- Above item in respect of cost and time needs to be studied deeply and formulated data accordingly.
- Client is mostly affected with quality of product in the long-term due to the unprofessional construction measures of contractor. This area needs to be explored.
- Early warning mechanism forecasting potential of rework needs to be benchmarked
- Rework–caused delays in construction projects.
- Introduce a rework performing index that can be calculated during the execution of a project in order to measure project performance in respect to rework.
- The impact of rework on a construction schedule has not been fully investigated along with actual measures and remedies.

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Primary Factors		Secondary Factors	Work Category									
			SO	RRM	BW	RCC	PW	TW	WP	P	C	A&G
Design and Engineering Factors	**SM secondary factors**	Changes in Design (to on site condition,client request	SO(7)	RRM(11)	BW(3)	RCC(6)		TW(3)		P(1)		A&G(3)
		Errors or omissions in Drawings and Specifications(unclear)	SO(3)	RRM(1)		RCC(6)						
		Lack of coordination among design consultants	SO(1)	RRM(1)	BW(1)	RCC(2)	PW(1)					
		Changes made at the request of an end user/regulatory body	SO(2)			RCC(1)					C(1)	
		Insufficient time to prepare contract documentation										
		Inadequate client brief to prepare detailed documentation										
Client Factors		Lack of experience and knowledge of DC process										
		Lack of funding allocation for site investigations										
		Inadequate client participation at the design stage		RRM(1),	BW(3)	RCC(1)		TW(1)	WP(2)	P(1)	C(1)	A&G(1)
		Low fees payment for preparing contract documentation										
		Changes made by client at the construction stage	SO(3)	RRM(1),	BW(4)	RCC(3)		TW(2)		P(1)	C(1)	A&G(1)

Table 4.1 Field Rework Data Summary

Site M Factors	Planning and schedulling	Poor planning and scheduling of construction resources	SO(3)									
		Poor application of realistic work procedures/construction method	SO(3)							P(1)		
		Poor planning of workload	SO(1)			RCC(1)	PW(1)					A&G(1)
		Ineffective use of quality management practices	SO(1)		BW(3)	RCC(1)	PW(1)	TW(1)	WP(1)			A&G(1)
		Ineffective use of IT										
	Leadership and communication	Lack of standard communication procedures	SO(1)			RCC(1)				P(1)		A&G(1)
		Misalignment of expectations from constractor ,sub contractor				RCC(1)						
		Unclear instructions to workers	SO(1)			RCC(1)				P(1)		A&G(1)
	Knowledge and Supervision	Incomplete supervision due to lack of technical knowledge	SO(6)	RRM(3)	BW(1)	RCC(1)		TW(3)		P(1)	C(2)	
		Poor workmanship		RRM(6)	BW(7)	RCC(2)	PW(13)	TW(11)	WP(4)	P(4)	C(5)	A&G(4)
		Failure to provide protection to the works	SO(3)				PW(1)	TW(2)	WP(8)	P(10)		A&G(6)
		Insufficient managerial and supervisory skills	SO(3)	RRM(3)	BW(6)	RCC(5)	PW(5)	TW(10)	WP(5)	P(8)	C(1)	A&G(5)
		Low labour skills level		RRM(2)	BW(4)	RCC(3)	PW(3)	TW(3)	WP(1)	P(1)	C(1)	A&G(2)
	Material & Equipment use	Non-compliance with specification		RRM(1)	BW(1)	RCC(3)			WP(1)	P(1)	C(3)	
		Inadequate material/equipment protection for delivery						TW(2)			C(1)	A&G(1)
		Equipment and tools not sufficiently advanced				RCC(1)					C(1)	
		Use of substandard materials/wrong material			BW(2)	RCC(5)	PW(2)	TW(2)			C(7)	A&G(4)

Table 4.1 Field Rework Data Summary

CHECKLIST For Brick Work	
Item	**Inspection Parameter**
1	**Quality of materials available for use: whether prior approval is taken**
2	Bricks
3	Sand
4	Cement
5	**Readiness for work**
6	Check setting out of walls (offsets need subsequent checks).
7	Check wall thickness.
8	Check corners/tees are at right angles.
9	Check provisions of expansion joints as per design
10	Check for details of Openings, Embedment's etc. [Size, Shape, Position etc.]
11	Check mortar mix with specification / BOQ.
12	Check whether Bricks/Blocks are adequately wetted.
13	Check existing walls, columns are set to meet new walls
14	Check that the bricks are correctly positioned in every layer as per type of bond, especially at corners/tees
15	Check joints and bedding mortar thickness.
16	Check for lintels/cill beams over Openings.
17	Check whether timber frames are available.
18	**Workflow Checks**
19	Subsequent checks for verticality.
20	Check RCC / masonry joints / bonds.
21	Subsequent checks for levelness of courses
22	Subsequent checks for workmanship/skill
23	Check one time continuity height of wall
24	Check for correct height of wall.
25	Check whether the debris has been removed on completion.
26	Check curing of wall after the period of completion

Table: 4.2 Checklists for Brick Work

CHECKLIST FOR Floor Tiling	
Item	**Inspection Parameters**
1	**Quality of materials available for work: whether prior approval is taken**
2	Sand
3	Cement
4	Tiles -tile specification/code:size,color,texturefinish
5	Tiles grout-specification,color,material
6	**Preparation for Screed Laying**
7	Check for surface preparation,cleanliness,roughness required
8	Check required cross/falls
9	Check minimum thickness of screed
10	Check provision of expansion joints
11	Check mix proportion to specification
12	Check whether finished levels match other areas.
13	Check whether adequate level drops placed.
14	Check any dryness of surface while leveling mortar
15	Subsequent checks for workmanship/skill
16	**Preparation for Tile Laying**
17	Check for surface preparation,cleanliness,roughness required
18	Check for approved tile specification-Type/Identification or code no.
19	Check whether approved shop drawing followed,laying pattern,design
20	Check setting out done as per shop drawing
21	Check that adequate references are marked to control errors being carried forward.
22	Check levels/cross/falls kept as per shop drawing
23	Check that tools & accessories are acceptable for use.
24	Check whether instructions are issued and understood by the workers with regard to skirting.
25	Check for protection and curing instructions.
26	Check while working for quality and specifications
27	Check for workmanship while working
28	Check whether arrangements are made for in-process & final inspection.
29	Check whether instructions are issued and agreed on final cleaning & polishing.
30	Check for protection and curing instructions.
Check for protection and curing instructions.	
32	Check whether instructions are issued and agreed on final cleaning & polishing.

Table: 4.3Checklists for Floor Tiling

CHECKLIST For Plastering	
Item	**Inspection Parameter**
1	**Quality of materials available for use: whether prior approval s taken**
	Cement
	Sand
5	**Surface Preparation**
1	Check for rebates / openings / embedment.
2	Check whether the surface is clean, and free from all dust, loose materials, grease, etc.
3	Check whether the surface is well wetted (dampened evenly).
4	Check for accuracy of finishing surface.
5	Check quality of additives if any
8	Check that mortar mix is as specified.
9	Ensure that plastering is left properly keyed.
10	Check whether the final finish is true and as per specified texture.
11	Check for dimensional accuracy of reveals, cills, openings [Size and Shape] etc.
12	Check Corners, Edges etc.
13	Check whether positions of frames and Embedment are acceptable compared to finished plaster line.
14	**Workflow checks**
15	Check frequently for verticality of surface
16	Check frequently for final finish required

Table: 4.4Checklists for Plastering

CHECKLIST For Ceiling Work	
Item	**Inspection Parameter**
1	**Quality of Materials available for use: whether prior approval is taken**
2	Species of timber/class
3	Moisture content
4	Wood preservatives
5	Other materials ,nails,anchorbolts
6	**Preparation for formation**
7	Check whether the correct drawing is in use
8	Check heights
9	Check lines and levels
10	Check whether the correct timber size and thickness is used
11	Check whether free from saps,shakes,cracks,large loose or dead knots and other imperfections
12	Check from attacks by insects
13	Check whether wood preservatives are applied as per specification
14	Check jointing details
15	Surface in contact with concrete or masonry
16	Check for fan holes, light points & other service installation & points

Table: 4.5Checklists for Ceiling Work

List of Appendices

Appendix A-Interview Guide

Questions for Interview

1.0 General Information Form

Contact Person: ---------------------------------------Designation: ------------------

Date of interview: ---

Company Name: ---

Name of theProject: -------------------------

Contact's Phone-------------------------------

Contact's E-mail Address: ---

Project Location---

Project Completed Date (MM/DD/Year):

2.0 Project Characteristics:

1. Principal type of building (up to 4 storey buildings):

   No of floors: Floor area:

2. Select the category that best describes the nature of this project:

   The Project Nature: New, Renovation Addition, Expansion (Pl underline)

3.0 Questions:

5. For each selected trades, what are causes for rework.
6. What best practices are proposed to minimize rework for each work category
7. What should be included as checklist indicators to minimize rework for each work category
8. Indicate any impact of rework on project performance or productivity other than cost and time

4.0 List causes for following trades in rework occurrences.

No	Work category	Causes(write down possible causes for these trades)
1	Setting out	
2	RRM	
3	Brick work	
4	Reinforced Concrete work	
5	Plaster work	
6	Tile work	
7	Waterproofing	
8	Painting	
9	Carpentry works	
10	Al and glass works	

5.0 Best practices to minimize rework/checklist indicators:

No	Work category	Proposed Best practices to minimize rework/checklist indicators:
1	Setting out	
2	RRM	
3	Brick work	
4	Reinforced Concrete work	
5	Plaster work	
6	Tile work	
7	Waterproofing	
8	Painting	
9	Carpentry works	
10	Al and glass works	

Appendix B-Supporting Documents-Possible Causes

1. **Design Changes**
    a. Changes made at the request of the unexpected site condition
    b. Changes made at the request of client
    c. Changes made at the request of an end user/regulatory body
    d. Errors in the contract documentation
    e. Omissions of items in the contract documentation.
2. **Construction Changes**
    a. Changes in construction method to improve constructability
    b. Changes in construction method due to site conditions
    c. Changes initiated by the client after work had been undertaken
    d. Changes initiated by the contractor to improve quality
    e. Errors due to inappropriate construction methods
    f. Omissions of some activity of task
    g. Damage caused by a subcontractor
    h. Poor workmanship
    i. Setting out errors
3. **Client related**
    a. Lack of knowledge of the D&C process
    b. Lack of funding allocated for site investigation
    c. Lack of client involvement in the project
    d. Inadequate time and money spent on the briefing process
    e. Poor communication with design consultants
    f. Payment of low fees for preparing contract documentation
4. **Site Management**
    a. Ineffective use of quality management practices
    b. Poor planning and coordination of resources(wrong material,equipmentand defective materials and equipment)
    c. Failure to provide protection to the works
    d. Poor coordination of design team members
    e. Time boxing
    f. Poor planning of workload
    g. Lack of skill manpower to complete tasks
    h. Ineffective use of IT
    i. Insufficient supervision
    j. Incompetent supervision
5. **Subcontractors**
    a. Damage to other trades due to carelessness
    b. Inadequate managerial and supervisory skills
    c. Low labour skills level
    d. Use of poor materials

Appendix C-Supporting Documents-Best Practices

1. **Project Scope**
   a. Project scope was re-evaluated before the project was documented
   b. Project scope definition was resolved before the project commenced
   c. End-users were involved in the development of scope
   d. Client had a disciplined approach to decision-making
2. **Contract Documentation**
   e. Contract documentation was of a high standard
   f. Contract documentation was cross-checked to ensure changes, were coordinated
   g. Design reviews and verifications were undertaken
   h. An assessment of the status of the design and the potential for change was provided to the contractor.
3. **Project Communications**
   a. Client's needs and practices were communicated to the project team
   b. The specifications for the performance and quality requirements for the building were clearly defined
   c. Roles and responsibilities of the project team were defined in terms of milestones
   d. Working procedures and communication lines were clearly defined
   e. Requests for information were answered in a timely manner
   f. Any change/error/omission that was identified was immediately reported and acted upon

4. **Procurement Strategy**
   a. Project quality management systems
   b. Prequalification
   c. Relational contracting
5. **Design Management**
   a. Value management
   b. Design for construction
   c. Computer visualization
   d. Involvement of subcontractors/suppliers during design
   e. Constructability analysis
   f. Design scope freezing
   g. Team building