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AN ANALYSIS OF THE CAUSES AND IMPACT OF REWORK IN CONSTRUCTION PROJECTS

by

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A dissertation presented to the Higher Degrees Committee of the Cape Peninsula University of Technology in fulfilment of the requirements for the degree of Master of Technology: Construction Management

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ABSTRACT

This study investigated the underlying causes of rework in construction projects and the impact on overall project performance so that effective containment and reduction strategies can be developed. The objectives of the study were as follows: (i) to determine the influence different project types have on the causes of rework in construction projects; (ii) to determine the impact of rework on organisational and project performance; (iii) to determine the influence various project types have on rework costs (direct and indirect) in construction projects; (iv) to determine the influence various procurement methods have on total rework costs in construction projects; (v) to design and develop rework reduction and containment strategies. The research was motivated by several international and local studies demonstrating a lack of concern for the root causes of rework and the potential impact on cost, overall project performance, and the 'value-addedness' to the completed project.

The research approach adopted included an exploratory and main study targeting purposively selected construction professionals and stakeholders in the Cape Peninsula metropolitan area of the Western Cape Province. The exploratory case study was carried out at the initial stage of the study to gain more insight into the causes and impact of rework on overall project performance. Specifically, data was collected by means of observation of physical works, semi-structured interviews with relevant parties directly involved in site operation and the analysis of site instruction record documents. The main study obtained data from 78 construction professionals and stakeholders via questionnaire survey, a survey conducted among design consultants and contractors in the general building category ranging from grade 3 to 9 who are registered with Construction Industry Development Board (CIDB). Descriptive, inferential statistics and probability distribution functions were used to analyse the data.

The findings revealed that changes initiated by the client, changes initiated by the design team due to errors and omissions, poor coordination, and finally, integration among the design team were the major contributing factors to rework. Moreover, non-compliance with specifications, setting-out errors, low labour skills, and emphasis on time and cost aggravated the occurrence of rework on site. The study revealed that while there is no significant difference between the causes of rework and various project types, rework can and often does make a significant contribution to any project's cost overrun. The total mean cost of rework as a percentage of the original contract value for new build project and refurbishment/renovation projects was 4.89% and 6.28% respectively. However, rework costs do not differ relative to project type or procurement method. Furthermore, the study revealed that cost overruns, time overruns and design team dissatisfaction all impacted on project performance. The findings indicate that design-related rework can be minimised by implementing the following strategies: team building, involvement of subcontractors and suppliers, and design for construction. Moreover, involvement of subcontractors during construction, and the implementation of quality control and site quality management systems could also lead to reduction in rework during the construction phase. Furthermore, the probabilistic analysis of rework occurrence was determined in the projects selected; this analysis predicts the occurrence of rework so that a quantitative risk assessment could be undertaken prior to the commencement of construction.

The research concludes by recommending that design and construction firms *must* develop organisational measurement systems for recording rework occurrence and its associated costs. It is by determining the frequency and costs of rework that effective strategies for its containment and reduction can be identified.

DECLARATION

I declare that, apart from the acknowledged assistance, this research is my own work and has not been submitted before for any degree or examination in any other university. It is submitted in fulfilment of the requirement for the Degree MAGISTER TECHNOLOGIAE: Construction Management to the Cape Peninsula University of Technology.

……………………………………   ………………………………………

Signed   Date

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LIST OF ABBREVIATIONS

CIBD	Construction Industry Development Board
CIDA	Construction Industry Development Agency
CII	Construction Industry Institute
COAA	Construction Owners Association of Alberta
CQSA	Construction Quality in South Africa
D & B	Design and Build
DIST	Department of Industry, Science and Tourism
ECSA	Engineering Council of South Africa
FIDIC	French acronym interpreted in English as International Federation of Consulting Engineers
NEDO	National Economic Development Office
SAPOA	South African Property Owners Association

CHAPTER ONE

INTRODUCTION

1.1 Background

The construction industry is faced with the significant problems of high cost of project delivery, bad financial performance and inability to deliver value to customers on time. As a result, the industry has been criticised extensively for poor performance and inefficient productivity. A major factor contributing to this setback is rework. Rework is defined as the unnecessary effort of redoing an activity that was inaccurately done the first time (Love, 2002a). In essence, rework and wastages have become recognised as non-value adding endemic symptoms that seriously affect the performance and productivity aspects of construction projects (Alwi, Hampson and Mohammed, 2002; Josephson, Larson and Li, 2002). Palaneeswaran (2006) stated that the construction industry is mainly project-based and various complexities are inherent in the construction projects such as dealing with diverse interests of multiple stakeholders and resultant changes. Due to these characteristic complexities of construction, amendments may be deemed inevitable in some instances; however, uncontrolled occurrences of rework and wastages should actually be more effectively controlled. This will essentially improve various targeted objectives of construction project management with respect to timeliness, cost targets and product and service quality (Palaneeswaran, 2006).

Rework is a major contributor to time wastage and schedule overruns which eventually impact on cost, resources and quality (Love and Edwards, 2004a). Cooper (1993) stated that rework emerges as overtime, the additional hiring of resources such as labour and plant workers, schedule slippage, and reductions in project scope and quality. The adverse consequences of rework include reduced profit, loss of market share, damaged reputation, increased turnover of management and workforce, lower productivity, higher costs, and finally, costly litigation between participants over responsibility for overruns and delays (Ackermann, Eden and Williams, 1997; Cooper, 1980; Eden, Williams and Howick, 2000). According to Davis, Lebetter and Burati (1989), the additional cost to construction caused by rework can be as high as 12.4% of the total project cost. Similarly, Love (2002a) suggested that rework typically increased total project costs by 12.6%. The actual costs could be substantially higher, however, because these findings did not account for schedule delays, litigation costs and other intangible costs of poor quality. The indirect cost of rework, according to Love (2002b), could be as much as six times the cost of rectification.

Love and Edwards (2004a) declared that construction professionals do recognise that rework contributes significantly to poor project performance. However, little is known about the background and consequently, rework remains an innate problem. Furthermore, because factors that contribute to its occurrence are not fully understood, the derivation of appropriate strategies for its reduction is problematic. Hence, a comprehensive appreciation of the mechanisms that cause rework will enable project performance improvements to be made (Love and Edwards, 2004a). The lack of attention to the root causes of rework seems to be a global phenomenon. With this in mind, the aim of this research is to determine the underlying causes of rework during construction, both its direct and indirect costs, as well as the impact of rework on overall project performance so that effective prevention strategies can be developed.

1.1.1 Sources of rework

Basically, rework can result from various sources such as errors, omissions and changes.

1.1.2 Errors

Love, Skitmore and Earl (1998b) indicated that rework is exacerbated by errors made during the design process, errors which then appear downstream in the procurement process. Love, Edwards, Irani and Walker (2009) argued that the longer an error goes undetected, the greater the likelihood of rework occurring that significantly impacts cost and schedule. The Construction Industry Institute (CII) (1989) study of nine large industrial construction projects found that rework due to design error contributed an average of 79% of total rework cost. According to Busby and Hughes (2004) and Cooper (1993), errors are often not readily identifiable and often only become evident after a period of incubation in the system. The extent of rework required, then, depends on how long the error has remained unnoticed. For instance, a dimensional error or spatial conflict contained within design documentation may not arise until the project is being physically constructed on-site (Cooper, 1993; Rodrigues and Bowers, 1996; Rodrigues and Williams, 1998). According to Love, Edwards and Irani (2005), errors occur as a result of a complex range of interactions, and hence attempting to isolate a singular contributory variable is an unseemly strategy to undertake. Once an understanding of the typical nature and underlying dynamics of errors is acquired, only then can error reduction and error containment strategies be implemented in projects (Love, Edwards and Irani, 2008).

1.1.3 Omissions

According to Reason (2002), omission errors arise when the mental process of action control is subjected to strain or distraction. Reason (2000) opined that omission errors are a result of pathogens within a system that translate into error-provoking conditions within the firm and project. Examples include time pressure, understaffing, fatigue and inexperience. He further lamented that pathogenic influences contribute to unworkable relationships and procedures as well as design and construction deficiencies which consequently contribute to rework. Failure to undertake procedural tasks during the design process (Andi and Minato, 2003a; Love, Edwards, Irani and Walker, 2009) and continual design reuse (Busby, 1999) are leitmotivs that emerge as practices contributing to omission errors. The work practices implemented by organisations can aggravate similar errors, regardless of the skills and experiences of the people involved in a project. A typical example is the study conducted by Love, Edwards, Irani and Walker (2009) to investigate the anatomy of omission errors in construction and resource engineering projects. The study revealed that the issue of design fees was identified by respondents in the construction sector as a factor contributing to an omission and design-related rework. Contractors and subcontractors are also susceptible to omission errors, as quality, safety and environmental management system constraints may not be always be strictly adhered to, and as a result, tasks or processes may need to be reworked.

1.1.4 Changes

Burati, Farrington and Ledbetter (1992) stated that a change is essentially a directed action that alters current established requirements. Changes can have an effect on the aesthetics and functional aspects of the building, the scope as well as the nature of work, or its operational aspects. According to CII (1990), rework, specifically in the form of changes can have a negative impact on productivity and project performance. Burati *et al*. (1992), moreover, stated that a design-change client, for example, would indicate that a client would initiate a change to the design of the building and therefore require rework due to redesign. Design-related rework in the form of change orders is the major source of rework in construction projects (Abdul- Rahman, 1993; Barber, Sheath, Tomkins & Graves, 2000; Burati *et al*., 1992; Josephson and Hammarlund, 1999; Love, Mandal & Li, 1999a).

1.2 Preliminary Literature review

1.2.1 Overview of rework factors

According to Love and Edwards (2004a), the root causes of rework can be categorised into three different groups: 1) client-related, 2) design-related and 3) contractor-related factors, including site management and subcontractor factors. A basic overview of such rework factors is as follows:

1.2.2 Client-related factors

Palaneeswaran (2006) identified some client-related factors: a lack of experience and knowledge of design and of the construction process; a lack of funding allocated for site investigation; a lack of client involvement in the project; inadequate briefing; poor communication with design consultants; and inadequacies in contract documentation. Deficiencies in communication flow between the client and design team members can result in documentation errors and omissions occurring (Dalty and Crawshaw, 1973). Walker (1994) stressed that clients and their project team members *must* communicate and work together harmoniously if projects are to be delivered on or ahead of time.

1.2.3 Design-related factors

Lack of design coordination and integration on the part of the design team leads to design deficiencies and exacerbates the causes of rework. This opinion is supported by Josephson and Hammarlund (1999) who pointed out that the source of design-related rework in construction is primarily communication problems. Similarly, Austin, Baldwin and Newton (1994) pointed out that the ineffective use of information technology in managing and communicating information aggravates the amount of rework that occurs in a project. One cited study, conducted by Love and Li (2000), quantified the causes and cost of rework on construction of residential homes and industrial warehouses. The study found that poor coordination and integration between design team members hindered the flow of information among them. Engineers used CAD technologies and the architects used manual systems to document their designs, and as a result, some drawings were issued with dimensional errors and missing information (Love and Li, 2000). Love, Davis, Ellis and Cheung (2010) argued that lack of professionalism by design professionals due to reduced design fees can further result in inadequate contract documentation being produced. This also leads to rework and may in the long run emerge as a dispute and consequently tarnish the image of participants.

1.2.4 Contractor-related factors

The inability of many supervisors to plan work, communicate with workers and direct activities adequately is fundamentally linked to increasing amounts and costs of rework (Business Roundtable, 1982). Site management team and subcontractors' project success is dependent upon the effectiveness of the main contractor's construction planning efforts (Chan, 1998; Faniran, Love and Li, 1999; Ireland, 1985; Walker, 1994). Cusack (1992) stressed that projects without a quality system in place typically experience a 10% cost increase because of rework. Other factors contributing to rework included:

- *Setting-out errors:* errors resulting from the misreading of dimensions on the working drawings and building out of alignment (Josephson and Hammarlund, 1999).
- *Disturbances in personnel planning:* errors resulting from in increased defects and poor workmanship which may arise as a result of excessive workload, multitasking and unwarranted pressures for early completion. Also, a disturbance in personnel planning occurs when staff is reallocated (Love, Mandal and Li, 1999a).
- *Failure to provide protection to works*: errors resulting from, for example, erection of scaffold on floor finishes such as tiling without protection. Also, failure to provide protection during painting work whereby paint splashes on floor finishes and sanitary fittings. Failure to protect certain parts of a building during alteration works (Barber *et al*., 2000).

In the case of subcontractors, Josephson *et al.* (2002), Love and Smith (2003), and Love *et al*. (1999a) found specific factors that contributed to rework: inadequate supervision, damage to other trade work due to carelessness, low skill level of construction artisans and labour, and poor choice of materials.

Love, Holt, Shen, Li and Irani (2002) highlighted that a large portion of rework costs are attributable to the poor skill levels of the client's project manager as well as the design team and subcontractors. According to Rounce (1998), a major source of non value-adding activities such as rework in construction projects can be traced back to poor managerial practices of individual firms involved in projects, especially those employed in architectural firms. Nesan and Holt (1999) stipulated that other stakeholders such as consulting engineers, contractors, and project managers who are integral to the procurement of projects are also prone to the implementation of poor managerial practices.

A report on construction industry status (CIDB, 2004), for instance, stated that only about half of all projects are delivered on schedule, within budget and relatively defect-free, and that there is low satisfaction with the performance of contractors and consulting professionals. Recent trends also show a reduction in skills in the South African construction industry. The Engineering Council of South Africa have noted that the number of professional engineers registering, although more representative, has declined in recent years (CIBD, 2004). The number of students registering for engineering and related studies such as civil engineering and building sciences has also declined. ECSA have also recorded a fourfold increase in the number of complaints pertaining to registered professionals in the last three years (Venter, 2006).

Smallwood (2000) conducted a study to investigate clients' perceptions relative to contactors' performances among members of South African Property Owners Association (SAPOA). The findings revealed that the causes of poor contractor performance as perceived by clients included the following: lack of concern for the environment, late information, poor management of the design activities, poor planning, overall poor management and low skills level among the workers.

1.3 Classification of rework

Hwang, Thomas, Haas and Caldas (2009) affirmed that in order to more effectively manage rework, it is first necessary to identify and classify its root causes. Many analysts have suggested that rework is often due to the intricate characteristics of the construction processes. Love and Edwards (2004) suggested a conceptual model of rework determinants including, for example, project characteristics, the organisational management practices of individual firms and the project management practices employed. Burati *et al*., (1992) also suggested a three-stage categorisation system to classify the types of rework identified. The first level refers to phases of the project that were affected—pre-planning, design, construction, procurement, construction start-up, operation, and disposal. The second level is used to determine the type of rework, that is, whether it is a result of change or error. The third level deals with categories of construction damage and construction change improvement (Nesan and Holt 1999).

1.4 Problem statement

The South African construction industry is under pressure from a combination of factors such as skills shortages, delays in payments, lack of standardisation, increased fee competition and variable quality (Loxton, 2004). Moreover, a study conducted by Smallwood (2000) to investigate clients' perceptions relative to contactors' performances among members of South African Property Owners Association (SAPOA) revealed that rework, poor productivity and poor quality are predominant problems in the industry. A study conducted in South

Africa by Rhodes and Smallwood (2003) revealed that the cost of rework was 13% of the value of completed construction. Based on the evidence from the preliminary literature gathered and the problems cited in the South African construction industry, the problem to be addressed may be stated as follows:

Unfortunately, rework has become an acceptable and regular feature of South African construction projects. The direct and indirect causes, such as lack of skills, poor coordination, inadequate site management, emphasis on time and cost and overall poor work organisation have not been fully examined in terms of their frequency and project phases. Furthermore, the impact of rework on cost and overall project performance has been overlooked.

1.5 Hypotheses

- H1: The causes of rework do not differ significantly between various project types.

- H2: There is significant correlation between the impact of rework on organisational performance and the causes of rework.

- H3: There is significant correlation between the impact of rework on project performance and the causes of rework.

- H4: The perceptions concerning the implementation of systems for measuring rework to improve the overall cost performance in a construction project do not differ among construction participants.

- H5: There is a significant difference between project type and total rework costs.

- H6: There is no significant difference between various procurement methods and total rework costs.

1.6 Aims and objectives

The aim of this study is to determine the underlying causes of rework during construction and the impact on overall project performance.

Specific objectives include the following:

- To determine the influence different project types have on the causes of rework in construction projects;
- To determine the impact of rework on organisational and project performance;
- To determine the influence various project types have on rework costs (direct and indirect) in construction projects;
- To determine the influence various procurement methods have on total rework costs in construction projects;
- To design and develop rework reduction and containment strategies.

1.7 Methodology

The research design will be descriptive in nature, comprised of an initial exploratory study and a questionnaire survey. The study population and the sample size will be confined within the Cape Peninsula area in the Western Cape Province. Purposive sampling will be used to obtain data from both consulting and construction companies. The exploratory study will be done using case studies and the data collection method will include semi-structured interviews with relevant parties, including the site management team, consultants and subcontractors. Additionally, observations of physical building and site documentary sources such as site instructions, revised working drawings and progress reports will be considered. A questionnaire survey will be used to gather information for the main study. The data analysis technique will include descriptive, inferential statistics and probability distribution functions.

1.8 Scope and Limitations

The study was limited to data gathered from the construction industry in the Cape Peninsula area in the Western Cape of South Africa. Information was gathered from the following stakeholders in both construction and consultancy firms: site managers, architects, quantity surveyors, project managers and engineers. External factors such as time and funding affected the study given that the time and funding available for the research extended from February 2010 to December 2011.

1.9 Key assumptions

It is assumed that rework has occurred on the selected construction projects that will be investigated.

It is assumed that the proposed participating companies identified for the survey will co-operate and allow access to their sites.

1.10 Key Concepts

Errors: unintentional deviations from correct and acceptable practices which are undeniably avoidable (Kaminetzky, 1991).

Non value-adding activity: activities that take in resources but do not add value to the final product (Saukkoriipi, 2005).

Omission errors: errors resulting from failures to follow due procedure when undertaking a task (Wills and Willis, 1996).

Rework: the unnecessary effort of redoing an activity because it was inaccurately done the first time (Love, 2002a:19).

1.11 Ethical Considerations

In order to comply with internationally accepted ethical standards, the name of participant organisations and individuals will not be recorded on research instruments. No compensation will be paid to any respondent or participant in the study. Quality assurance will be made with respect to the following aspects:

- general conduct and competence of interviewers
- quality of data captured
- accuracy in calculations
- correctness and completeness of questionnaires, especially with open-ended questions

1.12 Chapter outline

Chapter One: Introduction – the introductory chapter comprises the background information, the problem statement, hypotheses, aims and objectives, preliminary literature review, methodology, limitations, key concepts and chapter outline.

Chapter Two: Literature review – the literature review emphasises the previous works of numerous authors related to the study, discussing some of the literature related to the root causes and impact of rework in construction projects.

Chapter Three: Methodology – this chapter highlights the methodology utilised to drive through the study to establish the aims and objectives. It also discusses the sample size, data collection instruments and how these were administered.

Chapter Four: Analysis of exploratory study – this section comprises the presentation and analysis of the exploratory study conducted at the early stage of the research.

Chapter Five: Data analysis – this section reports the analysis and interpretation of the data gathered as represented in the form of tables and diagrams.

Chapter Six: Conclusions and recommendations – Based on the analysis, this chapter concludes the study and offers recommendations.

1.13 Chapter summary

This introductory chapter outlines the framework of the study. The historical background emphasised the fact that rework is wasteful and provided insight regarding the impact of rework in construction projects. The preliminary literature review focused on the sources, root causes and classification of rework. Subsequently, the problem statement and hypotheses were formulated based on the background information. The aim of the study is to determine the underlying causes of rework during construction and the impact of rework on overall project performance. The methodology adopted to drive through the research in order to achieve the aims and objectives has been outlined. The limitations of the study have been stated and the key concepts defined, including errors, non value-adding activity, omissions and rework. The research outline presented an overview of each chapter of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature pertaining to rework, covering, inter alia, the previous studies on rework pertaining to the South African construction industry, the nature of rework and rework as a waste of time and cost. This section will also discuss the pervasiveness of rework and factors influencing rework occurrence and their causes, the cost of rework and impact on construction projects.

Based upon the preliminary exploratory study conducted which provided the basis for the main study, an operational definition of rework was required to clearly indicate what is and what is not considered rework from the researcher's perspective as well as from an industry-wide perspective. For the purposes of the research, the operational definition for rework is as follows: ''the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time" (Love, 2002a:19). Rework will include the following: design errors and changes that affect construction activities, constructability errors, additional or missing scope due to designer or constructor errors and on-site fabrication errors that affect construction activities.

2.2 Previous studies on rework in the South African construction industry

The State of the South African Construction Industry's report compiled in June 2011 revealed that the gross fixed capital formation in non-residential buildings in South Africa in 2010 amounted to R41 928m which constitutes 2.3% of gross domestic product (GDP). Based upon prior research undertaken by Smallwood and Rwelamila (1996) among general contractors in South Africa which determined that rework constituted on average, 13% of the value of completed construction, the cost of rework in non-residential buildings could have been R5 451m. Rework in construction projects is attributable to lack of skills, quality management issues, lack of communication and coordination during design and construction, and emphasis on time and cost. In their status report, the Construction Industry Development Board (CIDB, 2004) revealed that design professions do not have enough knowledge of construction processes, and consequently, are not able to stay abreast of the changes in construction technologies. Furthermore, consultants do not provide sufficient design and construction process details, resulting in unnecessary design rework by contractors and construction delays. The CIDB (2004) also raised the issue of discounting of fees as a commonplace practice in the industry, in the order of 15 to 25%, with extremes of up to 50%. This discounting of fees places pressure on the quality of the work produced by consultants, who tailor their service to suit the price. Various studies conducted by Alman (1989), Smallwood and Rwelamila (1998) and Smallwood (2000) among architectural practices and general contractors consistently identified construction and procurement-related barriers as the dominant barriers to the achievement of quality, often together with design-related factors as additional barriers.

- *Design-related factors* identified by the authors include inadequate details, inadequate specifications and poor design coordination.
- *Procurement-related factors* include emphasis on time and budget, shortened project periods, lack of prequalification, competitive tendering and awarding of contracts primarily on price.
- *Construction-related factors* include skills shortages and insufficient workforce training, lack of management commitment and lack of strict quality control.

Rhodes and Smallwood (2003) examined defects and rework in South Africa. The findings of their study revealed that 38.5% of the respondents always recorded the incidence of rework, 15.4% often did, 7.7% sometimes did, 15.4% rarely did, 15.4% never did, and 7.7% were unsure. Those that did were requested to indicate whether their organisation costed rework. The study revealed that 10% always did, 30% often did, 40% sometimes did, and 20% rarely did. Relative to those organisations that costed rework, 90% of the respondents indicated that ≤ 5% of total work may be attributable to rework, and 10% indicated >5% ≤ 6%, suggesting that most construction companies in the South African industry have overlooked the incidence of rework and as such do not have mechanisms in place to track its causes and its impact on project performance. As a result, rework keeps on occurring unabatedly in the South African construction industry.

2.3 The nature of rework

The nature of rework can be determined by referring to the definition, interpretations and classification. Love (2002a) argued that rework has various definitions and interpretations within construction management literature. Synonymous terms for rework include “quality deviations”, “nonconformance”, “defects”, and “quality failures” (Burati, Farrington and Ledbetter, 1992; Abdul-Rahman, 1995; Josephson and Hammarlund, 1999; Barber, Graves, Hall, Sheath and Tomkins, 2000). Similarly, ‘field rework’ is defined as any activities that have to be done more than once or activities that remove work previously installed as part of a project (CII, 2001a). In the sense of conformance, there are two main definitions of rework (Love, 2002a; Fayek, Dissanayake and Campero, 2003). The first definition is that rework is the process by which an item is made to conform to the original requirements by completion or correction (Ashford, 1992). The second definition, given by the Construction Industry Development Agency (1995), holds that rework involves doing something at least one extra time due to nonconformance to requirements.

Feng, Tommelein and Booth (2008) classified rework as either positive or negative. Positive rework adds value, for instance, when designs are reworked and participants in the design process leave with a better understanding of customer requirements. Fundamentally, rework becomes necessary either when an element of building works fails to meet customer requirements, or when the completed work does not conform to the contract documents. In either scenario, the product is altered so as to ensure conformity (Feng *et al.,* 2008). Burati *et al.* (1992) used deviation categories based on construction, design, operability, fabrication and transportation to identify the causes of rework from nine fast-tracked industrial construction projects. Love, Wyatt and Mohamed (1997) proposed a rework classification system based on three principle groups: people, design and construction. Love *et al.* (1997) concluded that some causes are interrelated due to the complexity of construction operations. Love and Li (2000) also classified rework in three categories, namely client-initiated changes, non-variations, and defects.

2.4 Waste associated with rework

Koskela (1994) described the construction process as a combination of value-adding activities and non value-adding activities. Value-adding is to change the form, fit or function of a product in order to satisfy the customer (Allen, 2000). For instance, in the purchase of a constructed facility, Seibert, Seppanen, Kunz and Paulson (1996) stated that the buyer or owner values those components that are in place when the owner or end-user occupies the building. The activities essential to place these components are therefore clearly value-adding. Value-adding activities are only part of the work completed during a construction operation. Maximising the fraction of all activities that are value-adding increases the overall effectiveness in adding value during a construction operation (Seibert *et al.,* 1996).

On the other hand, Alarcon (1994), Koskela (1992) and Love, Mandel, and Li (1999a) stated that all those activities that produce costs, direct or indirect, and take time, resources or require storage but do not add value or progress to the product can be called non value-adding activities or waste. For instance, when rework ensues, numerous non value-adding activities with associated costs are likely to arise, activities which include idle plant and labour during the waiting time, demolitions, time taken by the designer to understand the required change and redesign, and cost and time for litigation in case misunderstanding arises between the contractor and the client or client's consultant (Ndihokubwayo, 2008). According to Alarcon (1994), Koskela (1992) and Love, Mandel, and Li (1997) waste categories are measured as a function of their costs, including opportunity costs. Furthermore, other types of waste are related to the efficiency of process, equipment or personnel. Ekanayake and Ofori (2000) classified construction waste into three main categories: materials, labour and machinery waste. However, any effort in terms of labour, materials and machinery which is directed towards the construction of a part or element of a building and which has to be done again due to non-conformity to the design constitutes a waste, which is also seen as rework.

Alarcon (1995) argued that construction activities are characterised by high contents of non value-adding activities leading to low productivity. For this reason, process improvement, through identifying and eliminating rework, has a significant impact on productivity. Love and Irani (2002) stated that non-productive time is waste as waste consists of inactivity and ineffective work. The authors stressed that inactivity includes waiting time, idling time, and travelling time. In the same vein, ineffective work includes rectifying mistakes and errors, working slowly and inventing work. In project-based transactions, any occurrence of rework is mainly considered as an unnecessary non-value adding item (Love, Mandal and Li, 1999a) that should be avoided if not completely eliminated. Fayek, Dissanayake and Compero (2003) intimated that rework costs are determined from the point where rework is initially identified to that final time when rework is completed and the activity has returned to its original state. The duration of the cost tracking includes the length of the standby time once rework is identified, the time required to carry out the rework, and the time required to gear up to carry on with the original scope of the activity. Saukkoriipi (2005) concluded that while most construction industry stakeholders are arguably interested in the reduction of overall production costs, they are not always aware of the extent of non-value adding activities on construction projects.

2.5 Pervasiveness of rework in construction projects

The construction industry has the iniquitous reputation of being fragmented, lacking co-ordination and communication between parties, creating adversarial contractual relationships and lacking customer focus (Love, Edwards and Smith 2005). Besides, there is generally an absence of systems within projects to monitor and control rework (Hwang, Thomas, Haas and Caldas, 2009). This combination of problems has meant that rework has become an insidious problem and consequently, the costs of rework have been found to be considerable (Love *et al*, 2005). Love, Holt, Shen, Li, and Irani (2002) stated that both the internal and external environments of construction projects are dynamic and relatively unstable. Tasks performed in construction projects are typically divided between professional disciples (architect, structural engineer, project manager) and trade disciplines (the contractors' and sub-contractors' carpenters, bricklayers, plumbers), which frequently operate independently of one another.

Oyewobi and Ogunsemi (2010) reported that the genesis of the problems experienced by the construction industry and clients lie in the division of the responsibilities between the design and the construction aspect. A direct criticism of the organisational structure of the construction industry by many researchers is that the construction industry is different in the sense that the design process is separated from construction process. Adejimi (2005) argued that construction is not well-connected or integrated until at the terminal end of each other rather than overlapping and mutually benefiting throughout the process. Adejimi (2005) further opined that if the design process is to be enhanced, the participants within the industry, including the architects, planners, engineers, contractors and the initiator of the process, need to come together in well-coordinated effort, especially if rework-free construction is to be attained. The occurrence of rework can be attributed to changes during the design and construction stage. Love (2002b) affirmed that a degree of change can be, and to a certain extent should be, expected in construction, as it is difficult for clients to visualise the end product that they procure. According to Bramble and Callahan (2000), most construction contracts give the owner the right to make changes within the general scope of the contract without breaching or invalidating the contract. Rework, nevertheless, often occurs and can usually be attributed to poor planning or devoting of insufficient time to the planning and design *before* commencing construction (Love, 2002a). Oyewobi and Ogunsemi (2010) stressed that a project must be well-conceived, must start right in order to end well. At the outset of the planning stages, the building owner, the initiator of the contract and the designer *must* come together and plan the work properly to prevent occurrence of rework. Inadequate planning can affect a well-conceived construction project, leaving all the participants—designers, clients and contractors—dissatisfied at the conclusion of the project. Thus, as construction involves the execution of a design envisioned by the architects and engineers, ineffective execution of this design process will unavoidably lead into rework and resultant time and cost overruns in both phase-design and construction (Oyewobi and Ogunsemi, 2010). The allocation of resources and planning of the documentation process are significantly important facets that need to be addressed if rework is to be reduced (Love, Mandal, Smith and Li, 2000).

While client involvement in projects has been identified as a factor that can contribute to project success (Walker, 1994; Chan, 1996; Love, Skitmore and Earl, 1998), their involvement may also lead to rework. A cited example is a study conducted by Love (2002a) to ascertain the influence of project type and procurement method on rework costs in building construction projects. Drawing on the qualitative comments provided by the respondents, a project manager stated that the ''client was a decision-maker and actively involved in construction, resulting in scope and design changes throughout the construction'' (Love 2002a). Oyewobi and Ogunsemi (2010) stated that one major factor responsible for having buildings that will require rework is lack of adequate information, build-ability of many designs and the separation the contracts interfaces, that is, separation of the design and construction interface, coupled with the fact that the construction processes are still sequential in nature. Indeed, the multitude of interfaces that exist between functional disciplines has unwittingly created a potential barrier to the effective and efficient flow of project information. Thus, the flow of physical resources and information from one discipline in a supply chain may become dysfunctional as rework emerges (Love, Edwards and Smith, 2005).

2.6 Factors influencing the occurrence of rework

Rework is expected to occur in all construction projects. Factors influencing its occurrence include the nature of the works, the procurement method and the complexity of the project.

2.6.1 Nature of the works

Construction works involve building, civil or specialist works. Building works include, for instance, the construction of residential houses, commercial premises and offices. Civil works include the construction of roads, bridges and infrastructural installations (Ndihokubwayo, 2008). Palaneeswaran (2006) indicated that there are more rework occurrences in building works than in civil works due to different interface-related management issues such as the lack of coordination between building contractors and building services, as well as poor communication between design team and construction team. According to Love and Wyatt (1997), construction projects involving refurbishment and renovations are prone to considerably higher rework costs than new build projects because of the degree of uncertainty and complexity associated with the building work undertaken.

2.6.2 Procurement and tendering method

Those involved in the procurement of buildings invariably do not realise the extent of rework that actually occurs (Love, Mandal and Li, 1999a). Love *et al.* (1999a) conceded that there is an escalating need to improve the quality of operations throughout the procurement process in order to reduce the occurrence of rework. The type of procurement method may then influence the extent of rework that might occur in a project. For instance, non-traditional methods are subject to higher rework levels than traditional methods, especially when errors, omissions, or changes occur (Love, 2002a). Traditional methods can provide clients with cost certainty, whereas non-traditional methods are often used when the pressure of early completion is imposed on the project (Holt, Proverbs and Love, 2000). Maizon (1996) concluded that one of the principal reasons for the construction industry's poor performance is the inappropriateness of the procurement systems selected for construction projects.

2.6.2.1 Traditional method

Morledge (2002) stated that under traditional methods (design-bid-build), such as traditional lump sum and traditional with provisional quantities, the cost can be determined with reasonable certainty before construction starts. In addition, Ibiyemi, Adenuga and Odusami (2008) maintained that the traditional approach provides a better pedestal for ensuring quality control. Moreover, under traditional methods, design and documentation are supposed to be complete, or at least largely complete, before construction commences on-site, so in theory there should be less rework attributable to design-related sources (Love, 2002a). However, traditional methods of procurement have been heavily criticised for their sequential approach to project delivery, as they have contributed to the so-called ''procurement gap'' whereby design and construction processes are separated from one another (Love, Gunasekaran and Li, 1998a). As a result, Love *et al.* (1998) suggest that behavioural, cultural and organisational differences exist between project individuals. In addition, the procurement gap that exists between design and construction inhibits communication, coordination, and integration among project team members which can subsequently cause rework and adversely affect project performance (Lahdenpera, 1995; Evbuomwan and Anumba, 1996). As a result, traditional procurement is not entirely suitable for fast-track projects (Construction Excellence, 2004).

2.6.2.2 Non-traditional methods

Hanna, Russell, Gotzin and Nordheim (1999) asserted that to satisfy the requirement of time, a plethora of non-traditional procurement methods have surfaced in the marketplace resulting in the compression of design and construction schedules and construction commencing before the final design is complete. As design and construction time is compressed, the degree of overlap, or concurrency, between activities increases which in turn increases project complexity as activities are sub-divided into trade packages (Love, 2002a). For instance, under design and build procurement method, a single contractor assumes the risk and responsibility for designing and building the project (Morledge, 2002).

Design and build method (D&B) is imputed with a time-saving mechanism which makes many activities overlap thereby minimising delay in completion time and reducing frequent adjustments in design (Ibiyemi, Adenuga and Odusami, 2008). One key advantage of using D&B is the opportunity to integrate the design and construction components; Saxon (2000) and Banik (2001) argued that integration of design and construction offers better performance in time and cost resulting in fewer defects.

With construction management procurement method, the client employs the design team and a construction manager is paid a certain fee to programme and coordinate the design and construction activities and to improve the build-ability of the design (Morledge, 2002). The management contracting, also known as a "fast-track" strategy, is suitable where all design work will not be complete before the first works contractors start work, although the design necessary for those packages must be complete. As design is completed, subsequent packages of work are tendered and let (Morledge, 2002).

The package deal, or turnkey procurement method, is where the client has little involvement in the design development or building procurement process, a complete hands-off approach (Morledge, 2002) which is less prone to rework. Hoedemaker, Blackburn, and VanWassenhove (1999) indicated that there is a limit to the number of tasks that can be carried out in a concurrent manner. Beyond this specified limit, the probability of rework occurring, as well as time and cost overruns being experienced, increases significantly, primarily due to the complexities associated with communication and coordination of a large number of tasks undertaken concurrently (Love, Mandal, Smith and Li, 2000). Non-traditional methods such as construction management and design and build have been advocated as methods for overcoming some of the problems inherent in traditional methods (NEDO, 1988; Turner, 1990; Masterman, 1994). Yet in a study conducted by Love (2002a) to establish the influence of project type and procurement method on rework costs in building construction projects, it was demonstrated that their use is minimal.

2.6.3 Complexity of the project

NEDO (1988) and Naoum and Mustapha (1994) indicated that facility types are linked to the concept of complexity and thus have influence on project performance. Baccarini (1996) declared that project complexity consists of many varied interrelated parts. Ireland (2007) stated that complexity involves an item having two or more components or two or more variables. Love, Li and Mandal (1999b) stated that in construction projects, activities are typically divided into functional areas performed by different disciplines such as architects, engineers, and contractors and that therefore operate independently. Customarily, each discipline makes decisions without considering the impact on others. Love and Irani (2002) maintained that these functional disciplines often develop their own objectives, goals and value systems. So, each discipline has become dedicated to the optimisation of its own function with little regard to its effects on the performance of the project as whole with which they are involved.

2.7 Causes of rework

Love, Mandal and Li (1999a) maintained that rework occurs when a product or service does not meet the requirements of the customer. Consequently, the product is altered in accordance with customers' requirements. No organisation participating in a project produces a substandard product or poorly performs a service intentionally; nevertheless, this is accepted as part of human nature. For a building to be procured, not only does it have to be produced to a desired quality, but it has to be constructed and delivered on time, in the right market and at minimum cost (Love *et al.* 1999a). Love *et al.* (1999a) asserted that in order to improve quality there is the need to understand the root causes of rework, that is, the basic reason for its existence or set of conditions that stimulate its occurrence in a process. Love and Edwards (2004a) suggested that the root causes of rework can be categorised into different groups: client-related, design-related and contractor-related factors including site management and subcontractor factors. Rework, however, has become an accepted part of the construction process. Bowen (1992); Koskela (1992) and Laufer (1997) suggested that the major cause of rework is uncertainty. Koskela and Huovila (1997) emphasised that this uncertainty is generated by poor information, information which often is missing, unreliable, inaccurate and conflicting. But the authors suggest that uncertainty is a consequence of numerous interrelated factors and not solely poor information. Therefore, to reduce rework, it is imperative to identify what its causes are, and then understand how these causes are interrelated (Rodrigues and Bowers, 1996). Palaneeswaran (2006) argued that to some extent, the level of rework in construction projects would depend on external factors such as excessive workload and market conditions. For example increased defects and poor workmanship may arise from limitations on the availability of good subcontractors and workers, and additional or unwarranted pressures for early completion. The Construction Owners Association of Alberta (COAA, 2001) developed the fish-bone classification system for categorising the causes of rework. The COAA used the fish-bone diagram, technically called the 'cause and effect diagram', to explore all the actual causes of rework. Figure 2.1 shows the fish-bone diagram adopted from Fayek, Dissanayake and Campero (2003) at the conclusion of a pilot study aimed at developing a standard methodology for measuring and classifying construction field rework. The fish-bone consists of five broad areas of rework and four possible causes in each of these areas. The five broad areas include the following: 1) human resource capability, 2) leadership and communication, 3) engineering and reviews, 4) construction planning, and schedule and 5) material and equipment supply.

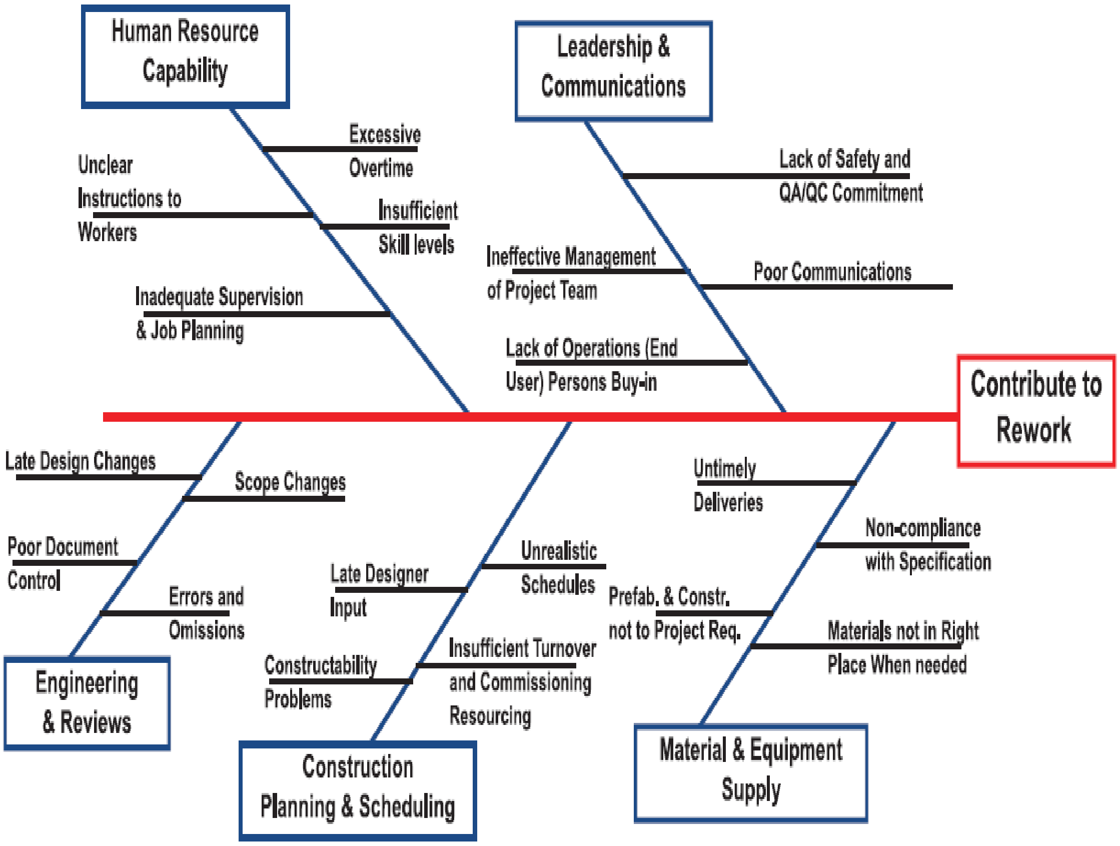

Figure 2.1: Rework cause classification
Adapted from: Fayek, Dissanayake and Campero (2003)

2.7.1 Human resource capability

Fayek, Dissanayake and Campero (2003) identified four possible causes of rework due to human resource capability: excessive overtime, insufficient skills levels, inadequate supervision and job planning and unclear instructions to workers. Similarly, The Business Roundtable (1982) found that lack of adequate planning, scheduling, materials management, quality control and quality assurance were critical problems during construction. Alwi, Hampson and Mohamed (2001) stated that inadequate supervision, inexperienced supervisors and lack of skilled labour are the major causes of rework. Therefore, experienced and well-trained supervisors have an important role in minimising the amount of rework due to construction defects. Apart from this, construction environments are characterised by problems related to production, general quality of work, design changes, material quality and availability and capacity utilisation (Akintoye, 1995). Moreover, Hampson (1997) stated that a major challenge facing today's construction project managers is encouraging innovation throughout the project process to ensure that all problems are easy to identify. Alwi *et al.* (2001) stated in a study to determine the effect of quality supervision on rework that the quality of site supervision has a major influence on the overall performance and efficiency of construction projects.

2.7.2 Leadership and communication

Hwang, Thomas, Haas and Caldas (2009) maintained that poor leadership and communication and ineffective decision-making cause rework. Love, Edward, Irani and Walker (2009) stated that the underlying contributors of rework due to poor leadership are strategic decisions taken by top management or key decision-makers who stimulate the conditions for the adoption of inappropriate structures, processes, practices and technologies for projects. Fayek *et al.* (2003) identified the following possible causes pertaining to leadership and communication: ineffective management of project team, lack of safety and quality assurance and control commitment, poor communication and lack of operation persons' buy-in. Alwi *et al.* (2001) affirmed that quality management principles and tools are not strongly embedded in conventional construction management practice. As a result, rework, on many cases, is accepted as an inevitable feature of the construction process increasing the likelihood of project time and cost overruns, and ultimately leading to client dissatisfaction. Likewise Jaafari, (1996) asserted that one of the most perplexing issues facing organizations in the construction industry is their inability to become quality focused. As a result substandard products and services often emanate, which inadvertently result in rework. The inability of supervisors to plan work, communicate with workers, and direct activities adequately is fundamentally linked to increasing amount and cost of rework. These abilities can be improved by formal training (The Business Roundtable, 1982). Clients and their project team members *must* communicate and work harmoniously if projects are to be delivered on or ahead of time (Walker, 1994). Love, Mandal and Li (1999a) concluded that poor communication leads to higher rework.

2.7.3 Engineering and reviews

Love and Li (2000) revealed that errors and omissions appear to be major contributing factors to rework. The Building Research Establishment in the UK (BRE, 1981) found that errors in buildings had 50% of their origin in the design stage and 40% in the construction stage. Lopez, Love, Edwards and Davis (2010) identified the following factors that cause design error in their study entitled “Design error classification, causation and prevention in construction engineering”: loss of biorhythm, adverse behaviour, inadequate training of design consultants and competitive fees, and ineffective utilisation of computer-aided automation. In addition, inadequate quality assurance, ineffective coordination and poor integration of the design team were also identified. A cited example in the research undertaken by Love and Li (2000) divulged that the architect’s documentation for the ceilings and partitions package contained dimensional errors and missing information, and thus affected the set-out of the internal walls. During construction, rework arose out of this incomplete and erroneous information. Every time a change was made in design, it had to be reworked by the design team, which in turn affected their fee (Love and Li, 2000). The other source of construction changes was direct from the architects, as they wanted to improve the functionality and aesthetics of the building (Love and Li, 2000). Moreover, Coles (1990) noted that the use of inexperienced and under-qualified staff lacking technical knowledge could also lead to errors and omissions in contract documentation being made. Lopez *et al.* (2010) argued that insufficient knowledge simply masks a more complicated problem inherent with design firms. In many cases, design firms use inexperienced staff so as to maximise their fees as well instigate “time boxing” practices, a practice which occurs when fixed durations are allocated to undertake tasks, irrespective of how complete (or incomplete) the design documentation or design task is, often to meet tight project schedules (Love, Edwards and Irani, 2008).

Sidwell (1982) also recognised the potential positive influence of client involvement in projects, concluding that by empowering clients in the design process, change orders (specifically design-related) during the construction phase can be minimised. However, this observation typically holds only for those clients who procure projects on a regular basis (Love, Skitmore and Earl, 1998b). Lopez *et al.* (2010) stated that unreasonable client and end-user expectations lead to design error. Busby (2001) concluded that many of the errors that occur are a result of designers’ failure to understand and deliver client requirements.

2.7.4 Construction planning and schedule

Mastenbroek (2010) stated that the work preparation before the design and construction stage is imperative. Love (2002a) argued that the occurrence of rework can usually be put down to poor planning or devoting of insufficient time to the planning and design before commencing construction. Similarly Hwang, Thomas, Haas and Caldas (2009) identified inadequate pre-project planning as a contributing factor to rework. For instance, changes due to improper planning contribute significantly to rework cost as opined by Josephson, Larsson and Li (2002), costs which could be as high as 34%, wrong information (15%) and bad planning method (15%). Mastenbroek (2010) stated that a change in construction methods can lead to rework on site as well as numerous indirect consequences such as stress. According to Alwi, Hampson and Mohamed (2001), project managers acknowledge that in some cases, the causes might be interrelated or lead to one another. For example, an inexperienced supervisor who makes a mistake in choosing the suitable construction method will certainly affect the construction process. Therefore, several construction methods should be considered and compared by analysing aspects of each such as costs, reliability, availability of knowledge and equipment and applicability (Mastenbroek, 2010).

2.8 Cost of rework

2.8.1 Overview of cost of rework

Love (2002b) stressed that there is a lack of uniformity in the way in which rework cost data have been collected because of the various interpretations as to what constitutes rework. Arguably, the measurement of rework costs in itself does not result in improvement; it merely provides the starting point for establishing new knowledge (Love and Holt, 2000). Love (2002b) suggested that design and construction organisations must implement a quality management system, supported by a quality cost system, in order to reduce the costs of rework. Only when organisations begin to measure their rework costs carefully will they fully appreciate the economic benefits of achieving high quality. Low and Yeo (1998) advocated that substantial reductions in appraisal costs can be achieved by eliminating the root causes of rework. Likewise, the BRE (1982) stated that 15% savings on total construction costs could be achieved through the elimination of rework, and by spending more time and money on prevention. To improve the performance of construction organisations and reduce costs, Davis *et al.* (1989), Abdul-Rahman (1993) and Low and Yeo (1998) have stressed the need to measure quality costs.

Love and Li (2000) agreed that prevention and appraisal costs are unavoidable costs that must be incurred by construction companies and consultant firms if their products and services are to be delivered right the first time. Figure 2.2 illustrates the quality cost components that must be incurred by construction organisations to improve their performance in order to reduce rework. The quality cost components are two-fold, namely cost of control and cost of failure control. The cost of control comprise prevention and appraisal cost. Love and Irani (2002) stated that prevention costs involve amounts invested to prevent or reduce errors and defects, whilst appraisal costs include the detection of errors or defects by measuring conformity to the required level of quality. Cost of failure control includes internal and external failure costs. Internal failure costs will be incurred as a result of scraping or reworking defective product or compensation for delays in delivery; on the other hand, external failure costs involves costs of repairs, returns, dealing with complaints and compensation after a product has been delivered to the client (Love and Irani, 2002).

Barber, Graves, Hall, Sheath and Tomkins (2000) acknowledged that rework costs could be as high as 23% of the contract value, with a number of factors contributing to rework cost. According to Love (2002b), these include the extent of quality management practices implemented, the type of project, the form of procurement method used, and project complexity. Love and Edwards (2004a) noted that the Construction Industry Development Authority in Australia found that the average cost of rework in projects without a formal quality management system is 6.5% of contract value and the high value for a project under lump sum procurement was 15%. Conversely, the average cost of rework for projects with a quality system was found to be 0.72%. The costs of rework in poorly managed projects can be as high as 25% of contract value and 10% of the total project costs (Barber *et al*, 2000; Love and Li, 2000). For example, the Construction Task Force in the UK reported that up to 30% of construction work is related to rework (Egan, 1998); similarly the USA based Construction Industry Institute has estimated that the annual loss due to rework could be as high as 15 billion US dollars for industrial construction projects (CII, 2001b). Josephson and Hammarlund (1999) reported that the cost of rework on residential, industrial, and commercial building projects ranged from 2% to 6% of their contract values. Love and Li (2000) found the cost of rework to be 3.15% and 2.40% of the contract value for a residential and an industrial building respectively. In addition, 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 less than 1% of the contract value. According to Cusack (1992), projects without a quality system in place typically experience a 10% cost increase because of rework.

Comparatively, the costs of quality deviations in civil and heavy industrial engineering projects have been found to be significantly higher. For example, Burati *et al,* (1992) studied nine major engineering projects to determine the cost associated with correcting deviations to meet specified requirements. The results of the study indicated that, for all nine projects, quality deviations accounted for an average of 12.4% of the contract value. A significantly lower figure was reported by Abdul-Rahman (1995) who found non-conformance costs (excluding material wastage and head office overheads) in a highway project to be 5% of the contract value. Love and Edwards (2005), from a national questionnaire survey in Australia, stated that the total cost of rework is a function of both direct and indirect rework costs. While there has been a plethora of research seeking to determine the direct (tangible) costs of rework, the indirect (intangible) costs remain unexplored in construction. This is because it is difficult, if not impossible, to quantify such costs in purely monetary terms (Love 2002b). Typically, research efforts have focused on determining direct rework costs at the expense of indirect costs which consequently remain relatively unknown (Josephson, 2000).

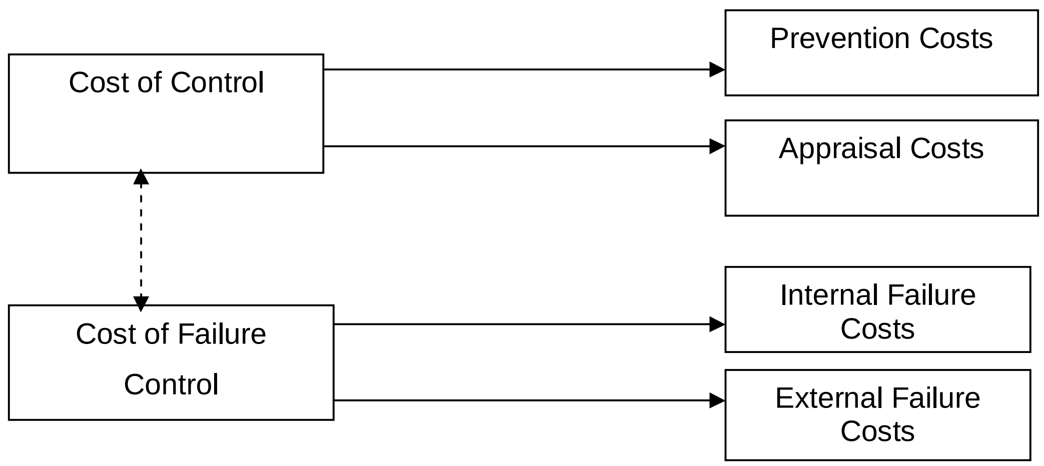

Figure 2.2: Quality cost components: cost of control and failure
Adapted from: Feigenbaum, 1991

2.8.1.1 Direct cost

Love (2002a) stressed that direct costs are readily measurable, often quoted in evaluating quality of workmanship and representing a significant proportion of total project costs. Tommelein, Ballard, Rundall, and Feng (2007) stated that direct rework cost includes manhour, schedule, equipment, materials and space. The Construction Industry Development Agency in Australia (CIDA, 1995) has estimated the direct cost of rework in construction to be greater than 10% of project cost. Thus, if a 10% rework value applied to the annual turnover of the Australian construction industry, which in 1996 was estimated to be $43.5 billion per annum (DIST, 1998), then the cost of rework could be estimated to be $4.3 billion per annum. Numerous studies have attempted to quantify the direct costs of rework in building and engineering projects (Burati *et al.*, 1992). These direct costs (of rework) have been found to be as high as 25% of contract value (Barber *et al.*, 2000).

2.8.1.2 Indirect cost

Indirect costs are not directly measurable and include loss of schedule and productivity, litigation and claims, and low operational efficiency (Love 2002a). Similarly Tommelein, Ballard, Rundall, and Feng (2007) stated that indirect costs have to do with performance factors, changeover, coordination and network impacts. Love (2002b) opined that there is little known about the indirect consequences of rework in construction projects, especially the financial costs. Besides, there has been limited research that has sought to determine the indirect costs of rework in construction projects. In a study conducted by Love (2002b) to audit the indirect consequences of rework in construction, he found that the most significant indirect cost for the drafting firm was related to the extension of its original contract period for the project, as this affected the organisation's capacity to take on new contracts. Furhermore, when information was made available, additional resources had to be employed and overtime paid, as deadlines needed to be met.

2.9 Impact of rework on construction projects

The occurrence of rework clearly has an adverse impact on project performance. Palaneeswaran (2006) maintained that rework has both direct and indirect impact on project performance. For instance, in poorly managed projects, the gross impacts of rework (that is, both direct and indirect) could be equal to or even exceed the anticipated mark up or profit margin levels. Also, in some cases there will be some carry forward ripple effects on different aspects such as stress, motivation, relationships and reputation. The author identified the following direct impact of rework on project management transactions: additional time to rework, additional costs for covering rework occurrences, additional materials for rework and subsequent wastage handling, and additional labour for rework and related extensions of supervising manpower. Love (2002b) concluded that rework can seriously affect an individual, an organisation and a project's performance indirectly. A summary of the indirect impact of rework can be seen in Figure 2.3. At the individual level, stress, fatigue, absenteeism, de-motivation, and poor morale were found to be the primary indirect effects of rework. In fact, when an individual is subjected to prolonged work hours because of errors, changes or omissions, fatigue and stress are likely to emerge, increasing the likelihood of even further rework occurring (Abdul-Hamid and Madnick, 1991; Love, Mandal, Smith and Li, 2000). At the organisation level, Love (2002b) identified reduced profit, diminished professional image, inter-organisational conflict, loss of future work and poor morale as indirect effects of rework. At the project level, work inactivity such as waiting time, idle time, travelling time and end-user dissatisfaction were identified as indirect consequences of rework. Love (2002b) identified physiological and psychological consequences associated with undertaking rework. For example, increased stress due to the additional financial burden and the loss of profit, as well as having to re-do something again, can have de-motivating consequences. Chan and Kumaraswamy (1997) and Love (2002a) suggested that rework can adversely affect the performance and productivity of design and construction organisations. Additionally, it is a major factor contributing to time and cost overruns on construction projects. According Burati *et al*. (1992), rework specifically in the form of changes can have an effect on the aesthetics and functional aspects of the building, the scope as well as the nature of work, and its operational aspects. Rework adversely impacts construction project performance in terms of cost overruns, time overruns, quality degradation and professional relations.

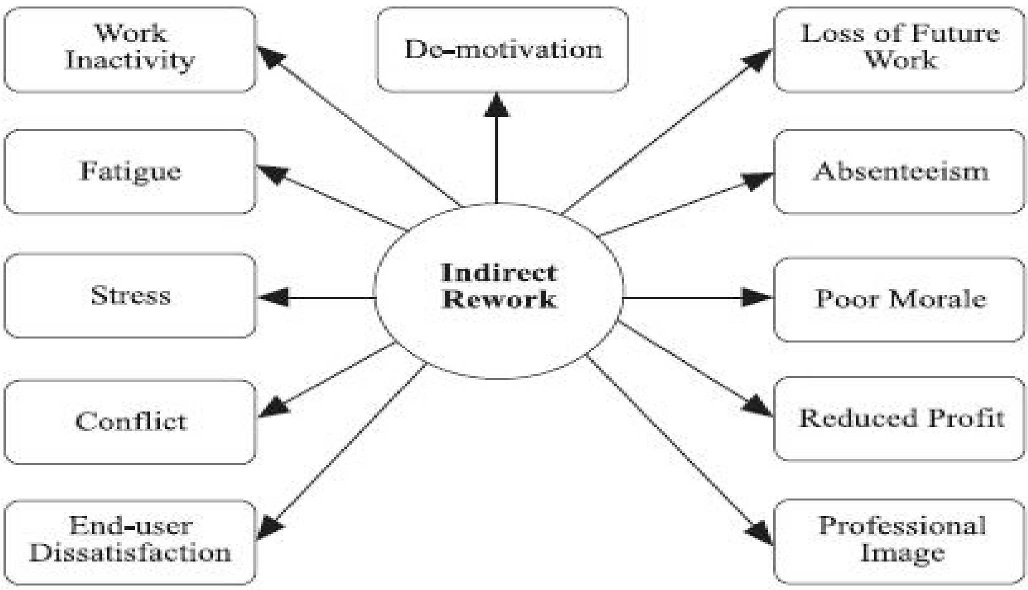

Figure 2.3: Taxonomy of the indirect impact of rework
Adapted from: Love, 2002b

2.9.1 Cost overruns

Azhar, Farooqui and Ahmed (2008) declared that cost overrun is a very frequent phenomenon and is associated with almost all projects within the construction industry. Cost has its proven importance as the prime factor for project success. Most of the significant factors affecting project costs are qualitative, such as client priority on construction time, contractor's planning capability, procurement methods and market conditions including the level of construction activity (Elchaig, Boussabinaine, and Ballal, 2005). Unfortunately, many construction projects incur cost overruns as a result of rework. Love (2002a) stated that rework is an occurrence that consultants do try hard to avoid because it leads to potentially high to cost increases. Cost overrun can be defined simply as situations in which the final cost of the project exceeds the original estimates (Avots, 1983). Endut, Akintoye and Kelly (2005) stated that cost overruns are major problems in project development and yet are regular features in the construction industry especially for developing country. This makes projects costly for the parties involved in construction, especially for contractors and clients. A study undertaken by Odeck (2004) for the Norwegian Public Roads Administration showed that cost overruns ranged from 59% to 183% and this was more predominant on smaller projects compared with larger ones. Aibinu and Jogboro's (2002) study indicated that the Nigerian construction industry experienced as a mean percentage cost overruns of 17.34%. Other research conducted by Barrick and cited by Jackson (2002) on the United Kingdom construction industry found that nearly one third of all clients complained that their projects generally overran budget. Creedy (2004) is of the view that identification of the existence and influence of cost overrun risk factors in a project can lead to a better control of project cost overrun and also can help in proposing feasible solutions for avoiding future overruns. Angelo and Reina (2002) stated that the problem of cost overruns is critical and needs to be studied more extensively in order to alleviate these overruns in the future. Angelo and Reina (2002) also pointed out that cost overruns are a major problem in both developing and developed countries. The trend is more severe in developing countries where these overruns sometimes exceed 100% of the anticipated cost of the project.

2.9.2 Time overrun

Endut, Akintoye and Kelly (2005) defined construction project time overrun as an extension of time beyond the agreed contractual time during the tender. Rework can lead to a significant extension of a project's time overrun. During the construction phase, rework extends project delivery and cost. According to Endut *et al.* (2005) the impact of project time overrun or delays for contractors include increased costs, reduced profit margin and battered reputation. Furthermore, clients are also affected by additional charges and professional fees and reduced incomes resulting from delayed occupancy. As part of the factors responsible for delays in construction completion, Ng, Mak, Skitmore, Ka, and Varnam (2001) noted that most contractors assume that duration set by the client is realistic and prepare their bid accordingly. Love (2002a) affirmed that the occurrence of rework will invariably result in the contractors re-evaluating their project schedules, as delays have the potential to lead to the incurring of liquidated damages. For instance, if a delay occurs due to rework and the contractor is not responsible, then an extension of time or acceleration costs may be awarded, though this will depend on the type of delay and how it impacts the critical path. Forty four percent (44%) of the respondents in the research undertaken by Elinwa and Joshua (2001) concerning the Nigerian construction industry indicate that time overrun occurred quite often. Scott (1993), Alkass *et al.* (1995,1996), Abdul Majid and McCaffer (1998), Al-Khalil and Al-Ghafly (1999) have all shown that time overruns occur on the majority of major civil engineering contracts and that this is a most common problem.

A cited example is a pilot study conducted by Palaneeswaran (2006) in Hong Kong, reducing rework to enhance project performance levels. In one sampled private building project, the time overrun was 277days, for which the original period at the award of contract was 480 days. Completing projects within the time is an indication of an efficient construction industry (Chan and Kumaraswamy, 1997). According to Chan and Kumaraswamy (1995), the ability to estimate the completion time is normally dependent on the intuition, skill and experience of the individual planning engineer. Mezher and Tawil (1998), however, noted that as time overruns in the Lebanon construction industry are costing the country a great deal of money, there is an undeniable need to find more effective methods for overcoming rework problems.

2.9.3 Quality degradation

According to Construction Quality in South Africa (CQSA) (2011), value to clients is a very complex and often a subjective issue, but it is recognised that quality of construction is a key component of perceived value to clients. As noted by FIDIC, lack of quality in construction is manifested in poor or non-sustainable workmanship and unsafe structures, and in delays, cost overruns and disputes in construction contracts. Mastenbroek (2010) stated that rework often means that parts of a structure have to be scrapped and new material needed to rebuild, a result of compromise with quality which leads to wastage of resources.

2.9.4 Professional relations

Love and Edwards (2004b) maintained that one of the resultant ripple impacts of rework is damaged reputation and goodwill. Endut, Akintoye and Kelly (2005) affirmed that one impact of project time overrun or delays for contractors includes battered reputation. A cited example is a study undertaken by Love (2002b) to examine the indirect consequences of rework in construction. The contractor found it difficult to organise many of the subcontractors to return to site to rectify defective and incomplete work, as most were working on other projects. Consequently, some work such as re-installing general purpose outlets, sanitary appliances, re-installing locks to doors, and painting had to be undertaken after purchasers had moved into their units. Many of the purchasers considered this an inconvenience and consequently blamed the contractor for the incomplete and poor quality work. In this respect, the intangible costs to the contractor’s image are greater than may at first be appreciated.

2.10 Chapter summary

The literature examines the causes and effect of rework in the construction industries in several countries. The ultimate aim of the South African construction companies should be to eliminate *all* incidents of rework in order to maximise profit and provide adequate customer satisfaction. The first literature provides context for the study by reviewing a brief history of rework pertaining to the South African construction industry. The literature study indicated that little is known about rework causes, and because of this, there are no mechanisms in place for tracking the costs and impact or rework on project performance.

Rework in construction projects has the potential to unnecessarily absorb resources without adding value to the project in which case rework is waste. Rework can potentially occur on all construction projects, as its pervasiveness is due to the complex nature of the industry. It was also noted that the fragmented nature of the industry intensifies the frequency of rework because activities performed are divided between professionals and trade disciplines which frequently operate independently of one another and have different objectives to achieve. Coupled with that, the design process is separated from the construction process. The literature suggested that the nature of the works, the procurement method and the complexity of the project were factors that influence the occurrence of rework in construction projects.

A knowledge and understanding of how rework emanates will possibly inform how the incidence of rework can be reduced and even possibly eliminated. Client-related, design-related and contractor-related factors including site management and subcontractor factors were the three origin agents of rework identified. Five broad possible causes of rework were established, including human resource capability, leadership and communication, engineering and reviews, construction planning and schedule, and material and equipment supply. Moreover, rework cost is dependent on a number of factors, such as the extent of quality management practices implemented, the type of project, the form of procurement method used, and project complexity. Rework can potentially increase the total cost of construction. Therefore, the literature suggested that design firms and construction organisations must establish mechanisms for tracking rework costs and implement quality systems in order to minimise rework costs. Two types of costs associated with rework were identified, direct and indirect costs. However, little is known about the indirect (intangible) costs in construction because it is difficult, if not impossible, to quantify such costs in pure monetary terms.

Finally, the literature highlighted that rework adversely affects construction project performance by contributing to cost and time overruns. It was established that the frequent occurrence of rework can affect the overall quality of work and tarnish the professional image of parties involved (consulting firms, design team and construction organisations) in the projects. Rework may also give rise to disputes between contracted parties.

The next chapter will propose a research design best suited to identify the causes and effects of rework in construction projects.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The methodology chapter discusses and explains the research design which was used to acquire the data to be analysed. Also, the sampling size and techniques, as well as the data collection procedure which includes the questionnaire design and administering the questionnaire, have been described. In addition, the data analysis techniques, testing of the hypotheses and validity and reliability of the data collection instrument have been outlined.

3.2 Research design

The research methodology covers the scope of the study, the collection and analysis of the data and the development of the conclusions and recommendations. Bell (2005) stated that the research design methodology chosen is an important part of any research project, as it gives the overall framework for collecting and formulating the data needed for the research. The argument presented by Leedy and Ormrod (2010) concerning the choice of research method is used as a basis, where consideration should be given to the nature of the data that will be collected in the resolution of the problem. Moreover, Leedy and Ormrod (2010) suggested that a pragmatic presentation regarding the data may be perhaps most expeditiously handled if the following four principal questions with respect to research data are answered:

"What data are needed?" Data pertaining to the underlying causes of rework during construction and its impact on cost and overall project performance will be gathered.

"Where are the data located?" Data will be collected through engaging with senior management staff from both construction and consulting firms in the Cape Peninsula area.

"How will the data be obtained?" Data will be obtained through a self-administered questionnaire, containing both open and closed-ended questions, which will be formulated and distributed to get the data. Moreover, data will be obtained through interviews, observations of physical building and site documentary sources such as site instructions, revised working drawings and progress reports.

"How will the data be interpreted?" Field data will be analysed and compared to the literature and suggestions will be made as to effective strategies for rework reduction/elimination. Descriptive inferential statistics and probability distribution will be used to analyse the data.

Leedy and Ormrod (2010) concluded that the research methodology must help to explain what the nature of the data is, and what method is used to process them to arrive at final conclusions. A combination of two approaches, namely quantitative and qualitative methods was adopted to achieve the aim and objectives of the study

3.2.1 Quantitative Research

A quantitative research approach refers to research which counts things, analyses data statistically and quotes the results in numerical forms (Gomm, 2008). Struwig and Stead (2001) also maintained that quantitative research methodology approaches incorporate experimental studies, quasi-experimental studies, as well as exploratory and descriptive studies. Moreover, Leedy and Ormrod (2010) acknowledge that quantitative research methodology seeks explanations and predictions that will be generalisable. The intent is to establish, confirm or validate relationships, and to develop generalisations that contribute to existing theories. Quantitative methods in this study seek to quantify and categorise the causes of rework, trade associated with rework and its overall impact on cost and time.

3.2.2 Qualitative Research

According to Leedy and Ormrod (2010), qualitative research involves looking at characteristics, or qualities, that cannot easily be reduced to numerical values. Qualitative research focuses on phenomena that occur in natural settings and involves studying those phenomena in all their complexity (Leedy and Ormrod, 2010). In the context of this study, the literature suggests that a systematic approach and structured tracking mechanisms are essential for effectively tackling the inefficiencies related to rework. The qualitative method has been utilised to determine the true perceptions of the sample in the population relative to the impact of rework and measures to be implemented to minimise their causes. Qualitative studies are generally field focused. Leedy and Ormrod (2010) affirmed that qualitative research is often exploratory in nature, and observations may be used to build theory from the ground up. Gummesson (1991) also opined that data gathered and analysed in exploratory case studies provide the basis for more precise research directions in the future. A preliminary exploratory study was conducted to gain more insight with regard to the causes and impact of rework on construction projects. Leedy and Ormrod (2005) concluded that qualitative study is more likely to end with tentative answers or hypotheses about what was observed.

3.3 Population and Sample size

A selected number of cases in a population are referred to as the sample (Walliman, 2005). Fellows and Liu (2008) stated that, where the research study is concerned, it is necessary to obtain data from only a portion of the total population. Fellows and Liu (2008) further asserted that an important aspect of sampling is the determination of the size of the sample to be studied. Moreover, Leedy (1997) argued that sample size is dependent on the degree to which the sample population embodies the qualities and characteristics of the general population. More specifically, the first step in sampling for any research study would be to define the population. If the population is sufficiently small, a full population may be researched. However, in the majority of research projects, a sample must be taken as a representation of the population (Fellows and Liu, 2008).

3.4 Sampling techniques

The technique of non-probability sampling was adopted for this study. In non-probability sampling, there is no way of guaranteeing that each element of the population will be represented in the sample. Furthermore, some members of the population have little or no chance of being sampled (Leedy and Ormrod, 2010). However, Kothari (1995) argued that when using non-probability sampling, the particular units of the population which constitute the sample is purposively chosen on the basis that the small mass selected will be representative of the whole population.

3.4.1 Purposive sampling

In purposive sampling, people or other units are chosen for a particular purpose (Leedy and Ormrod, 2010). Purposive sampling is a useful sampling method consisting of receiving information from a sample of the population that one thinks knows most about the subject matter (Walliman, 2005). For instance, in the preliminary case study undertaken, purposive sampling method was used to select two construction projects based in Cape Town. The projects were selected on pragmatic considerations, namely their availability. Moreover, the respondents for the questionnaire will be deliberately chosen as representatives of the population in the Cape Peninsula area and the questionnaire will be designed to seek information from senior personnel within the organisations.

3.5 Data collection methods

3.5.1 Secondary data

Secondary data consists of the review of the literature pertaining to the study area of the research. According to Naoum (1998), literature review involves reading and evaluating what other people have written about one's subject area, both descriptive and analytical. The review of literature is descriptive, in that it describes the work of previous writers, yet analytical in the sense that it critically analyses the contribution of others with the purpose of identifying similarities and contradictions made by previous writers. Melville and Goddard (1996) suggested two distinct literature studies namely a preliminary and a full literature review.

A preliminary literature review relating to the sources and factors attributing to rework and its classification was undertaken to help gain an insight into the proposed objectives.

In addition to this, an extensive literature review was conducted to develop a coherent and comprehensive view of the following pertinent topics: the nature and pervasiveness of rework, the causes and costs of rework and how rework impacts cost, time, quality and overall project performance. The sources of information for compiling the literature review included textbooks, journals, conference proceedings, round table discussions, dissertations and theses.

3.5.2 Primary data

Primary data involves sources which collect data by direct, detached observation or measurement of phenomena in the real word, undisturbed by any intermediate interpreter (Walliman, 2005). Moreover, Leedy and Ormrod (2010:89) '*maintained that primary data are often the most valid, illuminating and most truth-manifesting*'. Primary data was collected in two stages.

Firstly, a preliminary exploratory study was carried out on two construction sites to identify and examine the origin and causes of rework and to develop a tool for measuring the cost and impact of rework. According to Neuman (2000:510), exploratory research can be defined as *'research into an area that has not been studied and in which a researcher wants to develop initial ideas and a more focused research question'.*

The two major data sources used for the exploratory study include the following: semi-structured interviews, observations of physical building and site documentary sources such as site instructions, revised working drawings and progress reports. The findings of the study provided the basis for the research design of the main study and the formulation of the hypotheses. Struwig and Stead (2001) concur that the major purpose of exploratory research is the development and clarification of ideas and the formulation of questions and hypotheses for more precise investigation at a later stage. A questionnaire survey was adopted for the main study, in which a closed and open–ended questionnaire was developed to solicit respondents' opinions about the causes of rework, associated costs and their impact on overall project performance.

3.5.2.1 Interviews

Best (1981) stressed that an interview is a discussion between two people, known as the interviewer and the interviewee. The interviewer initiates the interview for the specific aim of obtaining information pertinent to the researcher's field of study. According to Wimmer and Dominick (1994), a successful interview will uncover the participant's perspectives on a particular issue. Moreover, an interview allows for the respondent's behaviour to be observed, which can provide extensive insight into the opinions, motivations and feelings of the respondent. Furthermore, Best (1981) described the interview as a distinctive research technique, having three specific purposes. Firstly, it may be used as the principal means of gathering information, having direct bearing on the objectives of the research study. Secondly, it may be used to test the hypothesis, or to suggest new ones, or as an explanatory device to aid in the identification of variables and relationships. Finally, the interview may be used in conjunction with other methods in a research study. The method of semi-structured interviewing was adopted for the initial exploratory study.

Semi-structured interviews fill the spectrum between structured and unstructured interviews. They may vary in form quite widely, from a questionnaire-type interview with some probing, to a list of topic areas in which the respondents' answers are recorded (Fellows and Liu, 2008). A framework of questions for the interview was designed to collect information relating to the causes of rework on site, the influence of human resources capability and quality management practice on the occurrence of rework (see Appendix A). Other information included the effect of rework on the project's critical path, their companies and overall project performance. Relevant parties interviewed included the site management team and subcontractors. Respondents were informed of the focus of the interview prior to meeting. This allowed the respondents to adequately prepare for the interview in advance. Each interview was tape-recorded.

3.5.2.2 Observations and audit of site documentation

Direct observations of physical buildings were made and notes were taken with the aid of a notebook and pen to derive data. Also, site documentation such as site instructions, revised working drawings and progress reports were examined to obtain data.

3.5.2.3 Questionnaires

A questionnaire is an instrument which enables one to gather data beyond his physical reach, without seeing the source from which the data has originated. A questionnaire is, therefore, a totally impersonal probe. Because of the impersonality associated with questionnaires, a questionnaire needs to be governed by certain practical guidelines (Leedy and Ormrod, 2010).Firstly, the language used must be unmistakably clear, because what may be stated clearly in the questionnaire may be meaningless to the respondent. Secondly, questionnaires should be designed to fulfill a specific research objective, as questions are often inexpertly written, and this result in a low response rate (Leedy and Ormrod, 2010). Moreover, according to Fellows and Liu (2008), questionnaires should be unambiguous and uncomplicated for the respondent to answer. More specifically, questionnaires should not require extensive data gathering by the respondent to facilitate answering the questions.

Questionnaire design

The questions for the survey were formulated according to the research objectives and a model established during the literature study. The questionnaire is comprised of seven sections, namely: profile of respondents, project characteristics, organisational management practices of participants, causes of rework, impact of rework, measurement of rework costs and rework containment strategies.

The first section (section A) of the questionnaire requested information about the profile of respondents. The information gathered includes the role of the organisation and the current position of the respondents. Section B obtained information concerning the project and facility type, the contract value and duration, procurement method and the size of the project. Section C collected data from construction professional regarding their organisational management practices. Section D solicited information regarding the causes of rework. The causes of rework were categorised into factors such as client-related, design-related, site management and subcontractors related and gathering of data was carried out using a five Likert-scaled type questions.

Section E obtained data pertaining to the impact of rework. Likert-scaled type questions were designed to ascertain the level of impact of rework on cost, time and organisational and project performance. Section F was designed to quantify the costs of rework, and the questions were based on a five point Likert-scaled type. Finally, section G requested information relating to the need for reducing/preventing rework. This area was examined by asking participants to suggest suitable strategies that can be adopted in reducing/preventing the causes of rework. The questionnaire for the main study can be found in Appendix B.

Table 3.1 presents a summary of how the research objectives were addressed and a proposed guideline for the design of the questionnaire. Respondents and participants to be used in this survey will include the following: contractors, architects, mechanical engineers, electrical engineers, structural and quantity surveyors and project managers. Fellows and Liu (2008) stated that questionnaires may be administered by post or email/internet to respondents, to groups and personally to particular individuals. The questionnaires were administered in two ways, by email and hand-delivered. Fellows and Liu (2008) identified two forms of questionnaires which are opened or closed questionnaires, both of which were formulated to collect data.

Table 3.1: Questionnaire design

Section	Title	Objectives to be addressed
A	Profile of respondents	To determine the role of the firm.
B	Project characteristics	Type of project and facility, as well as other relevant details.
C	Organisational management practices	
D	Causes of rework	Objective 1
E	Impact of rework	Objective 2
F	Measurement of rework costs	Objective 3 Objective 4
G	Reduction/prevention of rework	Objective 5

<u>Open-ended questionnaire</u>

According to Fellows and Liu (2008), an open-ended questionnaire is designed to enable the respondent to answer the questions fully by answering in any manner and to the extent the respondent chooses. Furthermore, the motives, expectations and true feelings of the respondent surface when open-type questions are asked. However, Struwig and Stead (2001) argued that open questions may demand a difficult and time-consuming tabulation of responses.

<u>Closed-ended questionnaire</u>

A closed-ended questionnaire allows one to limit the number of responses by offering specific alternatives from which the respondent must choose one or more. It simplifies the recording, tabulation and editing process considerably (Struwig and Stead 2001). Furthermore, closed-type questions are exact and to the point, and therefore the responses are clear, enabling the responses of a similar nature to be grouped and quantified easily.

Fellows and Liu (2008) claimed that closed-type questions force the respondent to make artificial choices because the questions may be rigidly structured.

3.6 Data Analysis

Qualitative data, gathered by way of semi-structured interviews and observation during the exploratory study, was analysed using content analysis. First and foremost, the recorded data was transcribed. Subsequently, a framework for making comparisons and contrasts between the different respondents was created by looking for trends which are present in the whole set of interviews. The process was concluded by entering data evidence into relevant columns by compiling short sentences recorded from the interviews.

Quantitative analysis involves mathematical operations which quantifies the results in numerical values. Quantitative data extracted from closed ended questionnaires was encoded using the Statistical Package for the Social Science (SPSS) and results were carefully analysed statistically using both the descriptive and inferential statistics. The ‘EasyFit Professional 5.5’ and ‘StatAssist 5.5’ were used to analyse the probability distribution of rework.

3.6.1 Descriptive statistics

Struwig and Stead (2001) maintained that descriptive statistics provide statistical summaries of data. Descriptive statistics provide an overall, coherent and straightforward picture of a large amount of data. Descriptive analysis make use of measures of central tendency, which provide a single value which can be said to typify broadly the way the cases are split between the categories of a variable. There are three measures of central tendency namely; mode, mean and median (Henn, Weinstein and Foard, 2006).

3.6.2 Inferential statistics

Inferential statistics use samples of observations to infer observation probably found in a population. They assist in generalising the findings from the sample to the larger population (Struwig and Stead, 2001). In addition, Kothari (2004) stated that inferential statistics refer to a variety of tests to find out the validity of data with the aim of reaching conclusions. Inferential statistics were used in this study to validate the data collected through the t-test.

3.6.3 Probability distribution

Probability distribution was used to determine the occurrence of rework in the selected projects. The probability is a scale of measurement used to describe the likelihood of an event (Ayyub and McCuen, 2003). A probability distribution function is expressed as a real-valued function of the random variable (Ayyub and McCuen, 2003).

3.6.3.1 Probability density functions and cumulative distribution functions

Probability density function (PDF) is a mathematical expression that analyses a continuous random variable and defines the shape of the distribution (Vining and Kowalski, 2011). On the other hand, the cumulative distribution functions (CDF) is an ordinary real-valued function of a real variable, and it expresses the probabilities of semi-infinite intervals (Schwarzlander, 2011).

Probability density functions were developed using ‘EasyFit Professional 5.5’. A PDF for a continuous distribution can be expressed in terms of an integral between two points:

$$\int_{a}^{b} f(x)dx = P(a \le X \le b) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[Eq.1]}$$

Where,

F(x) = probability density function for the continuous random variable

a to *b* = interval between two points, if the interval is made infinitesimally small, *a* approaches*b* and *P(a ≤ X≤ b)* approaches zero

Adopted from: Vining and Kowalski (2011)

A cumulative distribution functions (CDF) was also produced. For theoretical continuous distributions, the CDF is expressed as a curve and denoted by:

$$F(x) = \int_{-\infty}^{x} f(t)dt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[Eq.2]}$$

Where,

$F(x)$ = cumulative distribution function for the random variable *x*

$\int_{-\infty}^{x} f(t)dt$ = integration of the probability density function *f(t)* of continuous random variable *x*.

Adopted from: Vining and Kowalski (2011)

The empirical CDF, which is displayed as a stepped discontinuous line and dependent on the number of bins, is represented by:

$$F_n(x) = \frac{1}{n} \cdot \text{[Number of observations} \le x] \quad \text{.................................... [Eq.3]}$$

Where,

n = the sample size, that is the maximum value used in determining the probability of rework

The PDF, CDF and distribution parameters (μ, k, σ) for continuous distributions were examined using the estimation method Maximum Likelihood Estimates.

3.6.3.2 'Goodness of Fit' test

A 'Goodness of Fit' test was used to ascertain whether the distribution of observed counts in the various categories of a categorical variable matches the expected distribution of counts under a hypothetical model for the data. The test assumes that a random sample of observations is taken from the population of interest (Elliot and Woodward, 2007). Using StatAssist 5.5, the 'best fit' distribution was then determined using the following 'Goodness of Fit' tests, which measure the compatibility of a random sample with a theoretical probability distribution:

- *Kolmogorov-Smirnov statistic (D)*: Based on the largest vertical difference between the theoretical and empirical CDF:

$$D = \max_{1 \le i \le n} \left(F(x_i) - \frac{i-1}{n}, \frac{i}{n} - F(x_i) \right) \quad \text{... [Eq.4]}$$

- *Anderson-Darling statistic (A^2)*: A general test to compare the fit of an observed CDF to an expected CDF. The test provides more weight to a distributions tails than the *Kolmogorov-Smirnov* test. The Anderson-Darling statistic is defined as:

$$A^2 = -n - \frac{1}{n} \sum_{i=1}^{n} (2i-1) \cdot \left[InF(x_i) + In\left(1 - F(x_{n-i+1})\right) \right] \quad \text{........................ [Eq.5]}$$

Where,

n = the sample size, that is the maximum value used in determining the probability of rework

i = minimum value used in determining the probability of rework

In = natural logarithm

The above 'Goodness of Fit' tests were used to test the null (H_o) and alternative hypotheses (H_1) that the datasets: H_0 - follow the specified distribution, and H_1 - do not follow the specified distribution. The hypothesis regarding the distributional form is rejected at the chosen significance level (α) if the statistics D and A^2 are greater than the critical value. For the purposes of this research, a 0.05 significance level was used to evaluate the null hypothesis. The P-value, in contrast to fixed α values, is calculated based on the test statistic and denotes the threshold value of the significance level in the sense that H_o will be accepted for all values of α less than the P-value. Once the 'best fit' distribution was identified, rework probabilities were calculated using the CDF. Then, to simulate the sample's randomness and derive rework probabilities, a *Mersenne Twister*, which is pseudorandom number-generating algorithm, was used to generate a sequence of numbers that approximated the sample to 1000 (Matsumoto and Nishimura, 1998).

3.6.3.3 General Pareto distribution

The results of the 'Goodness of Fit' tests revealed that *General Pareto* distribution provided the best fit for the dataset for total, direct and indirect rework costs. A Generalized Pareto is a skewed and heavy-tailed distribution. It is akin to an exponential distribution and is typically used to modify the tails of other distributions (Newman, 2005). The parameter k is a continuous shape parameter, while σ is a continuous scale parameter (σ >0) and μ is the continuous location parameter. The domain for a Pareto distribution is denoted as $\mu \leq x < +\infty$ for $k \geq 0$, and $\mu \leq x \leq -\sigma/k$ for $k < 0$. The PDF is expressed as:

$$F(x) = \begin{cases} \frac{1}{\sigma}\left(1 + k\frac{(x-\mu)}{\sigma}\right)^{-1-1/k} & k \neq 0 \\ \frac{1}{\sigma}\exp\left(-\frac{(x-\mu)}{\sigma}\right) & k = 0 \end{cases}$$

………………………………………………… [Eq.6]

The CDF is expressed as:

$$F(x) = \begin{cases} 1 - \left(1 + k\dfrac{(x-\mu)}{\sigma}\right)^{-1/k} & k \neq 0 \\ 1 - \exp\left(-\dfrac{(x-\mu)}{\sigma}\right) & k = 0 \end{cases}$$ ………………………………………… [Eq.7]

Where,

F(x) = cumulative distribution function

k = continuous shape parameter

σ = continuous scale parameter (*σ* >0)

μ = continuous location parameter

3.7 Testing of the hypotheses

Leedy and Ormrod (2010) stated that research hypotheses possibility will originate in the sub-problems, and a one-to-one correspondence frequently exists between the sub-problems and their corresponding hypotheses. A hypothesis provides a position from which one may initiate an exploration of the problem or sub-problem and also acts as a checkpoint against which to test the findings that the data reveal. According to Leedy and Ormrod (2010), '*hypothesis is a logical supposition, a reasonable guess an educated conjecture. It provides a tentative explanation for a phenomenon under investigation'*. Hypotheses are either supported or not supported by the data. The validity of the hypotheses in this study will be tested by means of the *t*-test, one-way analysis of variance (ANOVA) and linear regression.

3.7.1 *t*-test and one-way analysis of variance (ANOVA)

The *t*-test was applied to test for Hypothesis 1 while the one-way analysis of variance (ANOVA) was applied to test for Hypothesis 4, 5 and 6. The ANOVA and *t*-test are commonly used methods to evaluate the differences in means between two groups and more than two groups, respectively (Elliot and Woodward, 2007; Fellows and Liu, 2008).Struwig and Stead (2001) opined that the *t*-test is also used when the population standard deviation is unknown. Therefore, the population standard deviation was estimated based on the sample standard deviation. The levels of significance for the ANOVA and t-test were 0.05.

3.7.2 Linear regression

For Hypothesis 2 and 3 the linear regression model was calculated and statistically tested. The linear regression model is a method of determining the correlation between two variables (Elliot and Woodward, 2007). A level of significance of 0.05 was also applied for this analysis.

3.8 Validity and reliability of the data

According to Kirk and Miller (1986) and Silverman (2001), the issues of validity and reliability are important, for the reason that in them the objectivity and credibility of research is at stake. Perakyla (2004) stated that enhancing objectivity is a very concrete activity. It involves efforts to guarantee the accuracy and inclusiveness of recordings that the research is based on, as well as efforts to test the truthfulness of the analytic claims that are being made about those recordings. Validity and reliability take different forms depending on the nature of the research problem, the general methodology that will be used to address the problem and the nature of the data that are collected (Leedy and Ormrod, 2010).

3.8.1 Reliability

According to Grummesson (1991), reliability is the extent to which a method can be replicated by others under similar conditions. Likewise, Leedy and Ormrod (2010) defined reliability as the consistency with which a measuring instrument yields a certain result when the entity being measured has not changed. Gomm (2008) stated that internal consistency may be tested by using statistical tests such as Kuder-Richardson formula 20(KR-20) or Cronbach's co-efficient alpha, by split-half techniques or by factor analysis. In this research, an internal reliability test will be done on Likert-scaled type questions using the Cronbach's co-efficient alpha. The alpha coefficient ranges in value from 0 to 1, where higher values of alpha are more desirable. Oppenheim (1992) stated that data reliability is related to the data source and the identification of the position held by the person who completed the questionnaire.

3.8.2 Validity

According to Leedy and Ormrod (2010), validity of a measurement instrument is the extent to which the instrument measures what it is supposed to measure. Similarly, research validity simply refers to the correctness or credibility of the research findings (Maxwell, 1996). Golafshani (2003) stated that engaging various methods and data sources will lead to more valid, reliable and diverse construction of realities. According to Yin (2003), exploratory case studies involve two areas of validity namely: construct and external validity. Construct validity refers to the assertions about the effectiveness of the operational measures used in a study (Sackett and Larson, 1992). External validity refers to aspects of study that can be generalised (Yin, 2003). To improve the level of construct validity in this study, interviews conducted during the initial exploratory study were tape-recorded and subsequently transcribed. The transcribed documents were given to each person that had been interviewed to check and resolve any discrepancies that may have arisen and eliminate any interviewer partiality.

3.9 Research methodology justification

The objective of qualitative research is to gain and develop understanding, discover meaning and explain phenomena. Therefore, qualitative research methods were chosen to enable the researcher to develop a coherent and comprehensive view of insights into the causes and effect of rework during construction projects from the perspective of the respondents. In this light, the case study and the questionnaire survey approaches were implemented in this research study. More specifically, the questionnaire survey method provided a tool to gather data over and beyond the physical reach of the researcher.

3.10 Chapter summary

This chapter serves as a synopsis of the research methodology adopted for this study. Both quantitative and qualitative methods were adopted to investigate the causes and impact of rework. Methods of collecting both primary and secondary data have been outlined. This encompasses literature review, exploratory study and questionnaire surveys. Data analyses techniques required to test and validate the hypotheses have been discussed.

In the next chapter, the findings of the exploratory case study are presented and analysed.

CHAPTER FOUR

ANALYSIS OF THE EXPLORATORY STUDY

4.1 Introduction

This chapter presents the analysis of the data gathered at the early stage of the study. It was an exploratory study aimed at gaining more insight into the causes and impact of rework during construction. It discusses the overview of the methodology used to collect data, preparation for the interviews, analysis of project A, analysis of project B, and finally, formulates conclusions.

4.2 Methodology used for the exploratory study

The study was a comparative one which focused on two ongoing construction projects based in Bellville, herein referred to as Project A, and in Cape Town, herein referred to as Project B. In relation to Project A, the contract manager and site quantity survey were interviewed. In the case of Project B, three interviews were conducted with relevant parties, namely: the contract manager, planner and junior site manager. A semi-structured interview was designed to collect information relating to the causes of rework on site, the influence of human resources capability and quality management practice on the occurrence of rework. Other information included the effect of rework on the project's critical path, their companies and overall project performance. A copy of the semi-structured interview questions can be seen in Appendix A.

4.3 Analysis of Project A

4.3.1.1 Preparation of interview

Prior to conducting the interview, the contract manager on Project A was contacted by phone and informed about the purpose of the interview. The verbal arrangement was thereafter confirmed in writing with an email to highlight the purpose of the interview. The semi-structured questionnaire was sent as an attachment with the email and this assisted the respondent to prepare adequately for the interview in advance. The contractor's contract manager and quantity surveyor were interviewed on this project and the discussion was tape recorded using a mobile phone.

4.3.1.2 Project particulars

Project A consisted of a two-storey university residential apartment situated in the suburb of Bellville in Cape Town. The total floor area was 3800m^2. The project contained a total of 200beds, a communal kitchen, a television room and an open court yard with a landscaped area in the middle. The contract value for the development was R30 million with a contract period of 14 months, and the project was 60% complete at the time of conducting the interview. The project was procured using a competitive tender with bill of quantities and working drawings, with the client employing an architect as the project manager.

4.3.2 Contract manager interview

The interview with the contract manager on project A was conducted on Friday, 10 December 2010, at 10h15 on site in the contract manager's office and lasted 45 minutes. The contract manager discussed some of the situations that caused rework on site, which include changes initiated by parties involved, design errors, omissions and construction errors. According to the contract's manager, about 40% of the changes initiated on site constituted rework.

An example of a change requested from the architect stated, "a decision has been made regarding the type of pipe to be installed; it must be either high density polyethylene (HDPE) or polyvinyl chloride (PVC) pipe". At the time this decision was taken, the civil work contractor had already done the surface bed preparation in order to receive the concrete bed. As a result, the plumber had to excavate through the sub-base in order to lay the pipe which basically affected both the plumber and civil work contractor. The respondent indicated that unclear decision making on the part of the water reticulation engineer during the design stage triggered this anomaly.

In the case of design omissions, the contract manager gave one such example where the engineer's drawing layout indicated columns which needed to be off-shutter finished, whereas the architect's drawings provided no indication about the required finish. The contract manager attributed the omission to lack of information flow between the architect and structural engineer.

Regarding construction error, the architectural drawing specified that the cavity between the rough and facing brickwork must be 50mm. However, during the erection of the wall, it was realised that the cavity between the rough and facing brickwork was 10mm instead of 50mm. The contract manager attributed this to setting out error due to lack of concentration on the part of the main contractor's foreman. The contract manager acknowledged that rework had an impact on costs due to related extension (overtime) of supervising manpower and the associated costs. The contract manager further stressed that sometimes rework lead to a dilution of supervision on site**.** Also, rework led to the dissatisfaction of the design team, as well as the de-motivation and poor morale of subcontractors' on site. For instance, the plumbing subcontractor was a bit edgy because rework affected the plumbing trade on several occasions.

4.3.3 Site Quantity surveyor interview

The interview with the site quantity surveyor (QS) was conducted on 18 March 2011, at 10h00 on site in the quantity surveyor's office and lasted 10 minutes. The site QS shared some thoughts on how rework had an adverse impact on costs and the duration of the contract. These included additional time to rework and additional costs for covering rework occurrences such as materials for rework and subsequent wastage handling, as well as additional labour for rework and overtime costs. However, the QS revealed that there were no mechanisms in place for recording the incidence of rework and capturing their costs on site. The QS concluded that the type of project and procurement method used could influence the costs of rework. The QS cited an example, saying that on their previous project which was a renovation and alteration work, much rework ensued in comparison to the current project (a new build project) under construction.

4.4 Analysis of Project B

4.4.1 Preparation of interviews

Concerning Project B, the human resources department of the construction firm was first contacted by phone to make an appointment. Subsequently, an effort was made to meet the training manager in the board room at the head office to discuss the possibility of inviting their firm to participate in the study. The verbal discussion was confirmed in writing with an email indicating the main points that would be covered during the interview. The training manager replied to the email with the contact details of three sites that had indicated their interest to take part in the study. The contractor's contract manager, planner and junior site manager were interviewed on this project.

4.4.2 Project Particulars

Project B consisted of a 7-storey educational facility situated in Observatory, a suburb of Cape Town. The total floor area was 6000m^2. Among the facilities incorporated in this development were 887 units with en-suite bathroom, 91kitchens, two-court yards with a central communal area and underground parking. The project was a competitive tender with bills of quantities, and the contract value for the development was R286.6 million with a contract period of 22 months. At the time of conducting the interview the project was 50% complete. A project manager was employed to act as the client's representative.

4.4.3 Junior site manager interview

The interview was held on 7 December 2010, in the afternoon from 12h15 to 12h45 on site with the junior site manager. He shared his experiences in terms of the causes of rework. The junior site manager stated that some columns were demolished as a result of honeycombing after casting. The junior site manager stated that the concreters were not sure as to how to vibrate columns sized 1000x300mm, since they were used to casting small columns of 300x300mm. The cause of rework in this case can be attributed to low labour skill level and failure on the part of the subcontractor to provide training for the concreters. Furthermore, two more columns had to be demolished due to a setting out error, as some columns were 25mm out of place. Inexperience on the part of the leading hand, and lack of coordination between the leading hand and land surveyor were identified as contributing factors in this instance. Carelessness was evident on the part of the surveyor because points were not marked clearly, as well as the charge hand who was not sure of the grid line.

4.4.4 Contract manager interview

A half hour interview was held on 9 December 2010, from 9h30 to 10h00, with the contract manager during one of his morning site inspections. The contract manager indicated that many construction errors had occurred during the construction of the basement, ground and first floor en-suite concrete beams. The respondent disclosed that some of the beams were out of alignment which affected both the construction of the brick wall and plastering work. In some instances, it was evident that the thickness of the plastering was about 65mm instead of 25mm, and this was an additional cost (material and labour) to the contractor. He attributed the occurrence of rework to low labour skills levels, shortage of skilled labour, inexperience on the part of the leading hand and the trades foremen and the inability to interpret the structural drawing which he referred to as "lack of dynamics for structural design".

The contract manager claimed that the company had been previously involved with industrialised building construction, for example factories and warehouses. This project, being a high rise building, was actually a challenge to his company. At the time the research was being conducted, the contract manger indicated that the principal agent had issued their 16th revised drawings for the services drawing due to major changes in the services duct. The major revision ensued as a result of clashes and changes in service duct, and this subsequently affected the wet trade, where some portions of the brick wall were demolished to accommodate the service ducts. The contract manager attributed this to lack of coordination and communication on the part of the design team.

4.4.5 Planner interview

The interview was held on 9 December 2010, from 11h00 to 11h50 on site in the site meeting room, it lasted 50 minutes. The planner highlighted that the project experienced numerous reworks as a result of design changes initiated by the design team. The planner stated that one such example was made by the architect who specified changes to window sizes in a section on the first floor. However, all the windows were in place when the revised drawings were received. An instruction was issued by the architect to remove all windows and replace them with new ones in accordance with the new revision.

Concerning construction errors, the planner cited a case where the bricklayer put the wrong door frame in place on the first floor. The planner stated that "we later realized it was a mistake, so we have to take down the door frame and put in new one. The drawings we have for this job are very detailed so that is more from education point of view on the part of the main contractor because we set out the position of the door frame. For example, we erected 110mm thick wall between the kitchen and bedroom next to each other, we built the wall and the architect issued an instruction that we should change it 150mm thick wall".

The planner stated that some members of the design team were dissatisfied in the beginning as the drawings were not strictly followed (non-compliance with specification). The plumbing consultant was particularly dissatisfied with the work of the plumbing subcontractor. For instance, the gradient for the surface water drainage in one of the court yards was incorrect due to a setting out error on the part of the subcontractor. The contractor was also dissatisfied due to many changes on the part of the design team. The planner stated that morale of workers for certain trades, especially bricklayers, plumbers and electricians were affected by rework.

4.5 Chapter summary

The findings presented in the exploratory case study indicate that there is no difference in the causes of rework between Project A and Project B. In both projects, it was found that rework was attributable to changes initiated by the design team and design errors originating from poor detailing. Omissions due to poor coordination and integration amongst design team members and errors during the construction stage were also identified. In project A, it was established that there was no mechanism in place for tracking rework cost and it was also apparent that project type and procurement method could influence the causes and cost of rework. Lack of experience with various building types and construction techniques were apparent in Project B.

In the next chapter the findings of the questionnaire survey are presented, analysed and discussed.

CHAPTER FIVE

DATA ANALYSIS

5.1 Introduction

This chapter presents the analysis of the data gathered in the survey using the questionnaire. It discusses the pilot questionnaire, response rate of the questionnaire survey, profile of respondents in the study, project characteristics and reliability testing. This section also presents the interpretation and discussion of the results pertaining to the causes of rework, its impact, its direct and indirect costs and finally, containment strategies.

5.2 Pilot questionnaire

A pilot study was undertaken to verify the appropriateness of the first draft of the final questionnaire. A total of 20 questionnaires were distributed among a group of Master of Technology and Bachelor of Technology: Quantity Surveying and Construction Management students at the Cape Peninsula University of Technology. One hundred percent response rates were achieved and subsequently, a few amendments were made as a result of improperly answered questions.

5.3 Response rate of questionnaire survey

The data was gathered via questionnaire surveys from a total of 455 questionnaires distributed to construction professionals in the Cape Peninsula area in the Western Cape Province. Respondents included architects, contractors, consulting engineers, quantity surveyors and project managers. Four hundred and fifty five (455) questionnaires were sent via email to respondents; however, 56 questionnaires were undelivered and thus delivered mails were 399. Out of the 399 delivered questionnaires, 78 were duly completed and returned, representing a response rate of 19.5%. The majority of the questionnaires were collected in person while a minority of the respondents returned the questionnaires via fax and email.

5.4 Profile of respondents

5.4.1 Participant companies

This section presents types of the participant organisations, the current position and work experience of respondents. As seen in Figure 5.1, participant companies included contractors (39.0%), quantity surveyors (22.1%), architects (15.6%), consulting engineers (15.6%), and project managers (7.8%).

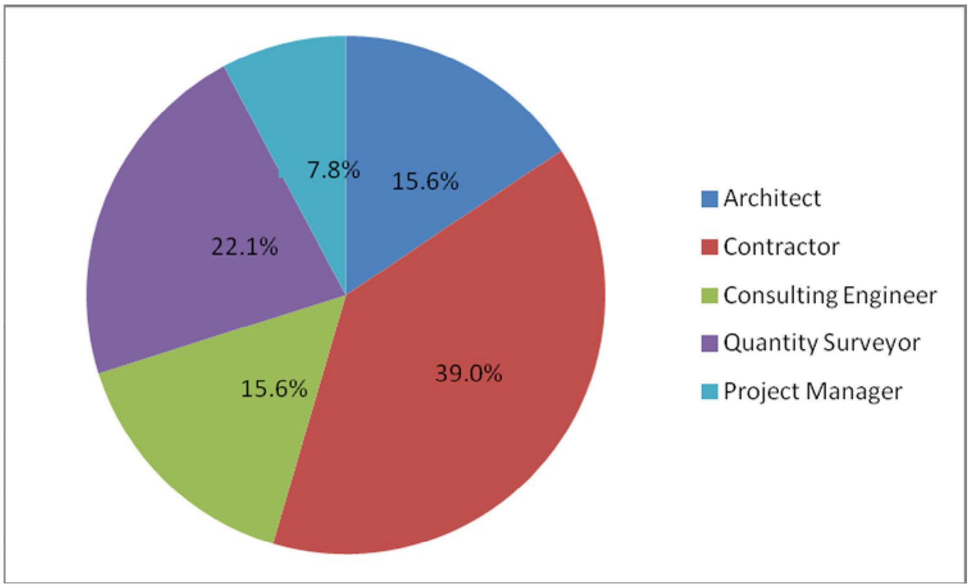

Figure 5.1: Participant companies

5.4.2 Experience of respondents

Table 5.1 shows that the experience of respondents in the construction industry ranged from three years to forty years, with a median experience of 15 years. While respondents had been in their present positions for a period ranging from ten 0.8 years (10 months) to 32 years, the median length of time that they had worked was 5 years.

Table 5.1: Experience of respondents

	N	Minimum	Median	Maximum
Number of years of employment in the construction industry	78	3.0	15.0	40.0
Number of years in present position	77	0.8	5.0	32.0

5.4.3 Position of respondents

Table 5.2 depicts the current position of the respondents. The survey population included construction professionals and other stakeholders as follows: owners (4), directors (4), partners (4), managing members (1) and commercial directors (1). Two (2) of the respondents owned a quantity surveying firm and the remaining two owned a construction company. Three (3) of the respondents were directors for a consulting engineering firm, and the other one for a quantity surveying firm. Four (4) respondents were partners, one (1) from an architectural firm, one (1) from a quantity surveying firm, one (1) from a consulting engineering firm and the remaining one (1) from a project management firm. In addition, one (1) of the participants was a managing member from a consulting engineering firm. And one (1) of the respondents was a commercial director for a construction company.

Table 5.2: Position of respondents

Current position	Frequency	Percentage
Architect	8	10.4
Contracts manager	6	7.8
Senior quantity surveyor	6	7.8
Site agent	6	7.8
Quantity surveyor	5	6.5
Junior quantity surveyor	5	6.5
Owner	4	5.2
Director	4	5.2
Partner	4	5.2
Chief engineer	3	3.9
Foreman	3	3.9
Junior foreman	3	3.9
Projects manager	3	3.9
Architectural technician	2	2.6
Planner	1	1.3
Managing member	1	1.3
Civil engineer	1	1.3
Commercial director	1	1.3
Sheq practitioner	1	1.3
Senior architect	1	1.3
Projects director	1	1.3
Technical manager/quantity surveyor	1	1.3
Structural Technician	1	1.3
Site manager	1	1.3
Assistant site agent	1	1.3
Senior contract surveyor	1	1.3
Site engineer	1	1.3
Senior engineer	1	1.3
Structural engineer	1	1.3
Total	**77**	**100.0**

5.5 Project characteristics

5.5.1 Project type

Figure 5.2 shows that most of the respondents (73.3%) were involved in new build projects, while 26.7% were involved in refurbishment work.

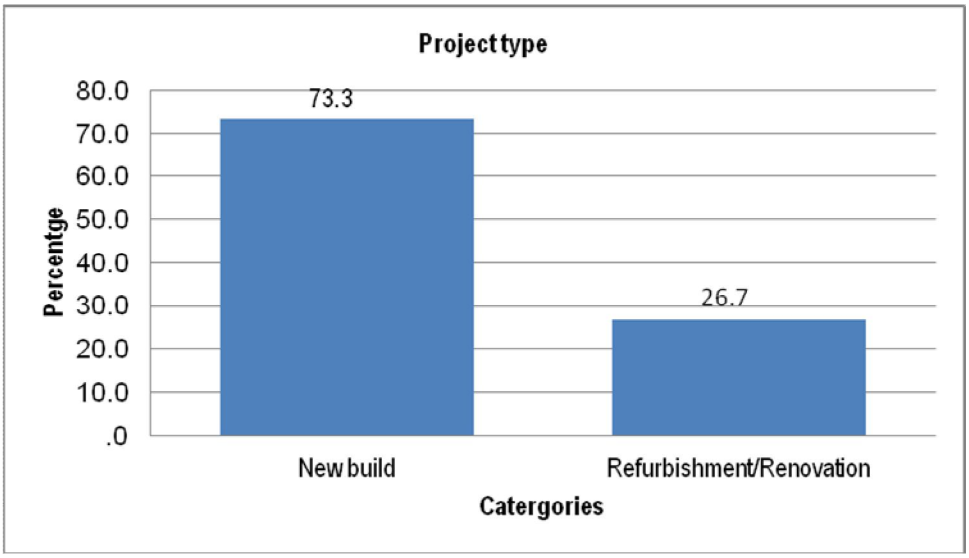

Figure 5.2: Project type

5.5.2 Facility type

From Figure 5.3 it is evident that respondents were involved in the procurement of a variety of facility types. The most popular facility types were commercial (18.4%), residential (18.4%), industrial (15.8%), and educational (10.5%).

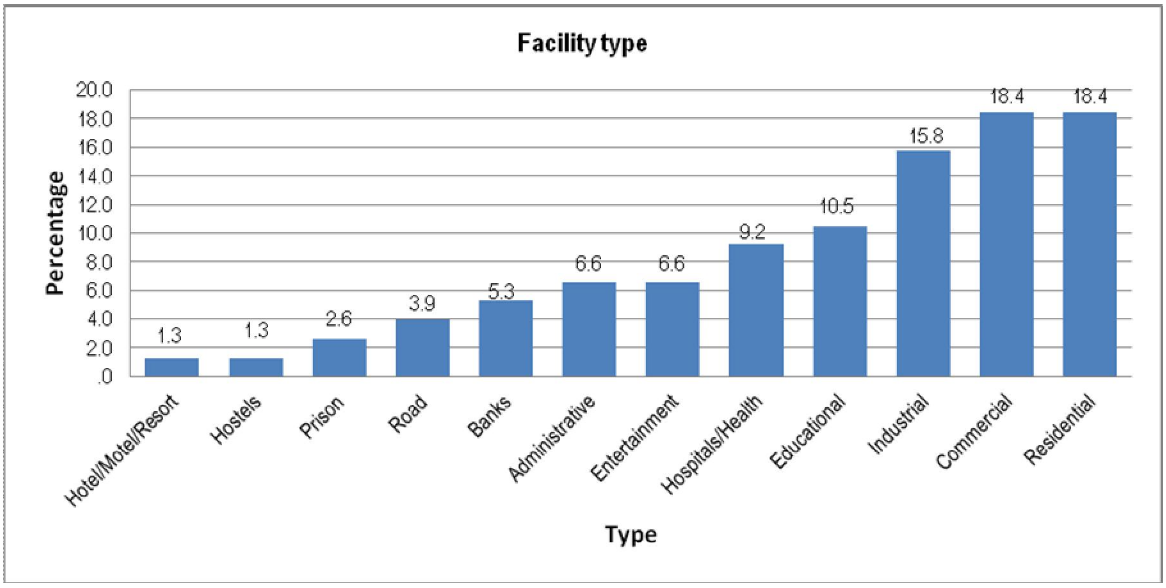

Figure 5.3: Facility type

5.5.3 Project Size

Table 5.3 identifies the project size by contract value, construction period, floor area and number of floors. The tender sums for the projects ranged from (in South African Rands) R1,928,000.00 to R2,740,000,000.00, (mean (*M*) = R128,936,809.79 and standard deviation

(*SD*) = R361,759,041.12). Likewise, the contract sums for the projects were found to range from R1,928,000.00 to R4,300,000,000.00, (*M* = R174,774,846.75 and *SD* = R562,442,037.77). Also, the original contract duration ranged from 4 months to 60 months (*M* = 13.72 months and *SD* = 10 months). Similarly, the actual construction period ranged from 4 months to 60 months with a mean value of 15.63 months and standard deviation 12.36 months. The gross floor area (GFA) for the projects was found to range from 221.4 m^2 to 100,000 m^2 (*M* = 9573.65m^2, *and SD* = 19448.67 m^2). The number of floors for the projects ranged from 1 to 32, (*M* = 3.49 and *SD* = 4.28).

Table 5.3: Project size

	N	Minimum	Maximum	Mean	Std Deviation
Tender sum (Rands)	64	1,928,000.00	2,740,000,000.00	128,936,809.79	361,759,041.12
Contract sum (Rands)	62	1,928,000.00	4,300,000,000.00	174,774,846.75	562,442,037.77
Original construction period (months)	77	4.00	60.00	13.72	10.07
Actual construction period (months)	76	4.00	60.00	15.63	12.36
Gross floor area (m^2)	65	221.40	100,000.00	9,573.65	19,448.67
Number of floors	70	1	32	3.49	4.28

5.5.4 Procurement method

Figure 5.4 shows that the most popular procurement methods used to deliver project types were traditional with provisional quantities (62.8%), traditional lump sum (16.7%) and design and manage (7.7%).

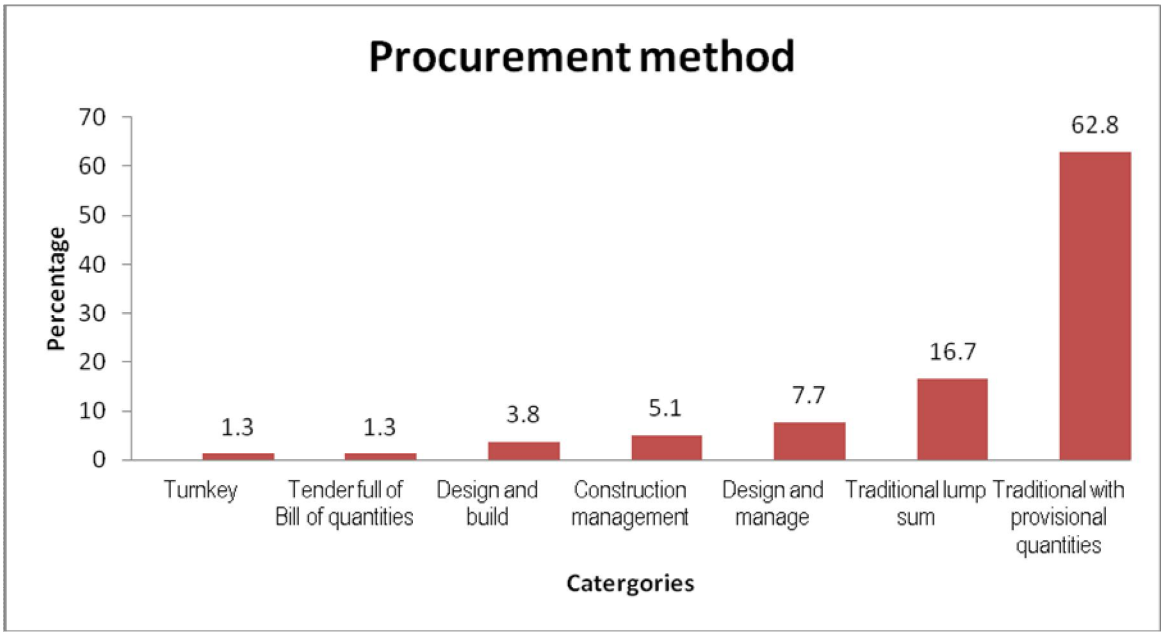

Figure 5.4: Procurement method

5.6 Reliability testing

The Cronbach's alpha coefficient was used to check the reliability of all the scaled questions. The overall Cronbach's alpha coefficient for all scaled questions was 0.9 which satisfies the reliability test requirements. Table 5.4 shows the summary of the reliability test for questions 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 28 and 29.

Table 5.4: Summary for reliability test

Question No	Statement	Number of items	Cronbach's alpha coefficient
14	Implementation of quality practices	5	0.9
15	Implementation of learning mechanisms	6	0.8
16	Causes of rework: Client-related factors	7	0.8
17	Causes of rework: Design-related factors	14	0.8
18	Causes of rework: Site management	9	0.8
19	Causes of rework: Subcontractor	8	0.9
20	Impact of rework on project performance	8	0.9
21	Impact of rework on organisation	7	0.9
23	Recording rework occurrences	4	0.8
24	Rework cost: Design-related source	6	0.7
25	Rework cost: construction related sources	8	0.8
26	Cost-sources	6	0.8
28	Containment strategy: Design management	7	0.8
29	Containment strategy: Site management	5	0.8
	All questions combined	100	0.9

5.7 Presentation of findings

5.7.1 Organisational management practices

5.7.1.1 Implementation of quality practices

Respondents were requested to indicate their perception concerning the quality management practices that were implemented using a 5-point Likert Scale where 1= not at all; 2 = to least extent; 3 = to some extent; 4 = to larger extent; and 5 = to a very large extent. From Table 5.5, it was possible to rank the implementation of quality practices using their means. Total quality management was ranked first with a mean score of 3.61, and quality functional deployment (3.47) and improvement and work teams (3.38) were ranked second and third respectively. Since all means of the responses were greater than 3, respondents tended to agree that implementation of quality management practice was important. Relative to other factors not mentioned in the questionnaire, one of the respondents added that quality assurance was one of the quality practices implemented by his firm.

Table 5.5: Implementation of quality practices

Quality Practices	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Total quality management	75	2.7	4.0	42.7	30.7	20.0	3.61	0.94	1
Quality function deployment	74	2.7	1.4	54.1	29.7	12.2	3.47	0.83	2
Improvement teams/work teams	76	1.3	11.8	46.1	28.9	11.8	3.38	0.89	3
Measurement of quality costs (e.g. Prevention and appraisal costs)	74	14.9	9.5	31.1	25.7	18.9	3.24	1.29	4
International Standards Organisation (e.g. ISO 900)	76	18.4	9.2	28.9	19.7	23.7	3.21	1.40	5

5.7.1.2 Learning mechanisms

The implementation of learning mechanisms was examined. The ranking by the mean of the responses pertaining to implementation of learning mechanisms is shown in Table 5.6. Project reviews was ranked first with a mean score of 3.38, followed by training programs for staff (3.23) and internal benchmarking (3.20). These findings indicate that learning mechanisms such as project reviews, training programs for staff and internal benchmarking were implemented to some extent. Relative to other learning mechanisms not mentioned in the questionnaire, one of the respondents added that new technology was one of the learning mechanisms implemented by his company.

Table 5.6: Learning mechanisms

Learning	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Project reviews	78	3.8	5.1	51.3	28.2	11.5	3.38	0.90	1
Training programs for staff	78	12.8	10.3	33.3	28.2	15.4	3.23	1.22	2
Internal benchmarking	76	3.9	15.8	44.7	27.6	7.9	3.20	0.94	3
Internal seminars on new developments	76	5.3	21.1	46.1	18.4	9.2	3.05	1.00	4
Self-learning of individuals (e.g. tradesmen on site)	76	19.7	17.1	31.6	23.7	7.9	2.83	1.23	5
Research and development	78	15.4	21.8	39.7	16.7	6.4	2.77	1.10	6

5.7.2 Causes of rework

5.7.2.1 Client-related factors

This section explored the knowledge of respondents about the causes of rework. Respondents were asked to indicate the extent to which the following client-related factors might be the cause of rework. Table 5.7 suggests that poor communication with design consultants was ranked first with a mean score of 3.58. Lack of experience and knowledge of the design process was ranked second with a mean score of 3.37 followed by lack of experience and knowledge of the construction process (3.24). Implicitly, respondents tended to agree that the first three client-related factors contributed to rework since their means are between 3 and 4. Regarding other factors not mentioned, one of the respondents suggested monitor time and cost implications as one of the client-related factors that caused rework while the other one agreed that using different architects for various areas of work led to rework.

Table 5.7: Client-related factors

Client-related factors	N	SD (%)	D (%)	N (%)	A (%)	SA (%)	Mean	Std Dev	Rank
Poor communication with design consultants (architect/engineers)	78	6.4	12.8	21.8	34.6	24.4	3.58	1.18	1
Lack of experience and knowledge of the design process	78	5.1	14.1	35.9	28.2	16.7	3.37	1.08	2
Lack of experience and knowledge of the construction process	78	6.4	16.7	35.9	28.2	12.8	3.24	1.08	3
Insufficient time and money spent on the briefing process	77	14.3	13.0	26.0	29.9	16.9	3.22	1.28	4
Lack of funding allocated for site investigations	76	10.5	19.7	26.3	27.6	15.8	3.18	1.23	5
Lack of client involvement in the project	78	14.1	20.5	21.8	33.3	10.3	3.05	1.24	6
Payment of low fees for preparing contract documentation	78	16.7	15.4	35.9	19.2	12.8	2.96	1.24	7

5.7.2.2. Design-related factors

The causes of rework attributed to design-related factors were identified. The results in Table 5.8 indicate the perception of respondents relative to design-related factors that led to rework. By ranking the means of the responses, changes made at the request of the client (4.03) was identified as the most frequent design-related factor contributing to rework. The next most frequent factor was incomplete design at the time of tender (3.96) and the third was omission of items from the contract documentation (3.63). Evidently, respondents agreed that the first three factors were the predominant source of design-related rework since their means are between 3 and 4. Two of the factors, poor planning of workload and changes initiated by the municipality or other regulatory bodies, recorded a mean value of 3.06 and 3.05 respectively, indicating that respondent tended to be neutral. However, the last two factors recorded a mean score less than 3 implying that respondents disagreed that those factors contributed to rework during the design stage.

Table 5.8: Design-related factors

Design-related factors	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Changes made at the request of the client	78	1.3	12.8	6.4	41.0	38.5	4.03	1.04	1
Incomplete design at the time of tender	78	7.7	7.7	11.5	26.9	46.2	3.96	1.26	2
Omissions of items from the contract documentation	78	1.3	14.1	24.4	41.0	19.2	3.63	1.00	3
Poor coordination of design	78	7.7	11.5	17.9	37.2	25.6	3.62	1.21	4
Changes made by the contractor during construction	77	5.2	13.0	27.3	39.0	15.6	3.47	1.07	5
Errors made in the contract documentation	78	3.8	15.4	28.2	39.7	12.8	3.42	1.03	6
Insufficient time to prepare contract documentation	78	7.7	15.4	21.8	39.7	15.4	3.40	1.16	7
Time boxing (that is, fixed time allocated to task, irrespective of whether the documentation is complete or not)	77	6.5	18.2	27.3	32.5	15.6	3.32	1.14	8
Inadequate client brief to prepare detailed contract documentation	77	11.7	13.0	23.4	35.1	16.9	3.32	1.24	8
Insufficient skill levels to complete the required task	78	10.3	19.2	28.2	26.9	15.4	3.18	1.21	10
Poor planning of workload	78	10.3	19.2	37.2	20.5	12.8	3.06	1.16	11
Changes initiated by the municipality/regulatory bodies	77	10.4	19.5	28.6	37.7	3.9	3.05	1.08	12
Ineffective use of quality management practices	77	5.2	23.4	45.5	19.5	6.5	2.99	0.95	13
Ineffective use of information technologies (e.g. CADD)	78	23.1	16.7	34.6	16.7	9.0	2.72	1.25	14

5.7.2.3 Site management-related factors

Table 5.9 presents the results relative to site management factors that contributed to rework. By ranking the means, the results show that setting out errors dominated with a mean value of 4.04, followed by lack of training and experience (3.93) and poor coordination of resources (3.86). These results indicate that setting out errors, lack of training and experience and poor coordination of resources were the major sources of site management-related rework since their mean scores were greater than 3.5.

Table 5.9: Site management factors

Site Management	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Setting out errors	77	5.2	9.1	7.8	32.5	45.5	4.04	1.18	1
Lack of training and experience	76	1.3	14.5	6.6	44.7	32.9	3.93	1.05	2
Poor coordination of resources (eg. subcontractors)	78	1.3	11.5	14.1	46.2	26.9	3.86	0.99	3
Constructability problems	77	0.0	15.6	20.8	46.8	16.9	3.65	0.94	4
Ineffective use of quality management practices	77	5.2	10.4	20.8	44.2	19.5	3.62	1.08	5
Poor planning of resources	78	2.6	10.3	26.9	46.2	14.1	3.59	0.95	6
Failure to provide protection to constructed works	78	10.3	12.8	19.2	41.0	16.7	3.41	1.21	7
Lack of safety	78	16.7	16.7	21.8	35.9	9.0	3.04	1.25	8
Excessive overtime	77	14.3	20.8	28.6	31.2	5.2	2.92	1.14	9

5.7.2.4 Subcontractor-related factors

Subcontractor-related rework was examined and Table 5.10 reveals the findings. After ranking the means of the responses, non-compliance with specification was rated as the most predominant subcontractor-related factor that contributed to rework (mean = 4.19), followed by low labour skill level (mean = 4.15) and shortage of skilled labour (mean = 4.13). Given that all means were greater than 4, respondents tended to agree that all the factors were considered to be subcontractor-related sources that contributed to rework.

Table 5.10: Subcontractor-related factors

Subcontractor	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Non-compliance with specification	78	1.3	5.1	12.8	34.6	46.2	4.19	0.94	1
Low labour skill level	78	2.6	2.6	6.4	53.8	34.6	4.15	0.85	2
Shortage of skilled labour	78	1.3	2.6	10.3	53.8	32.1	4.13	0.80	3
Shortage of skilled supervisors	78	2.6	3.8	14.1	47.4	32.1	4.03	0.93	4
Defective workmanship	78	3.8	1.3	19.2	39.7	35.9	4.03	0.98	4
Inadequate Supervisor / Foreman / Tradesmen ratios	78	2.6	3.8	14.1	55.1	24.4	3.95	0.88	6
Damage to other trades work due to carelessness	78	2.6	6.4	17.9	39.7	33.3	3.95	1.01	7
Unclear instruction to workers	78	2.6	12.8	15.4	35.9	33.3	3.85	1.11	8

5.7.3 Impact of rework

5.7.3.1 Impact of rework on project performance

Respondents were requested to indicate the extent to which rework affected the overall project performance on a 5-point Likert scale where 1= not at all; 2 = to least extent; 3 = to some extent; 4 = to larger extent; and 5 = to a very large extent. From table 5.11, it is evident from the ranking of the means of responses that cost overrun dominates with a mean score of 3.22, followed by time overrun with a mean score of 2.96 and design team dissatisfaction with a mean score of 2.46. This implies that respondents tended neither to agree nor disagree that these factors impacted on project performance since the mean values are hovering around the neutral point.

Table 5.11: Impact of rework on project performance

Project performance	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Cost overrun	78	3.8	15.4	46.2	24.4	10.3	3.22	0.96	1
Time overrun	78	15.4	14.1	41.0	17.9	11.5	2.96	1.19	2
Design team dissatisfaction	78	20.5	35.9	28.2	7.7	7.7	2.46	1.14	3
Contractual claims	78	32.1	21.8	29.5	12.8	3.8	2.35	1.17	4
Quality degradation	78	21.8	47.4	17.9	6.4	6.4	2.28	1.08	5
Contractor dissatisfaction	77	24.7	41.6	23.4	3.9	6.5	2.26	1.08	6
End-user/client dissatisfaction	78	30.8	33.3	21.8	9.0	5.1	2.24	1.14	7
Disputes between contracted parties	78	41.0	21.8	26.9	6.4	3.8	2.10	1.14	8

5.7.3.2 Impact of rework on organisations

Respondents were requested to indicate the extent to which rework impacted on their organisation's performance. The ranking of the means relative to the impact of rework on organisational performance is shown in Table 5.12: reduced profits were highly ranked with a mean score of 2.97, followed by de-motivation of workers (2.06) and inter-organisational conflict (1.96). This suggests feelings of disagreement and neutrality on the part of respondents that rework impacted on the performance of organisations since their means are hovering around 2 and 3.

Table 5.12: Impact of rework on organisation

Organisation	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std. Dev	Rank
Reduced profit	78	16.7	17.9	33.3	15.4	16.7	2.97	1.30	1
De-motivation of workers	78	39.7	26.9	24.4	5.1	3.8	2.06	1.10	2
Inter organizational conflict	78	41.0	26.9	28.2	2.6	1.3	1.96	0.96	3
Poor morale of workers	78	50.0	17.9	25.6	3.8	2.6	1.91	1.07	4
Fatigue	78	48.7	28.2	16.7	2.6	3.8	1.85	1.05	5
Absenteeism of workers	78	53.8	24.4	17.9	2.6	1.3	1.73	0.94	6
Loss of future work	77	54.5	29.9	10.4	2.6	2.6	1.69	0.95	7

5.7.4 Measurement of rework cost

5.7.4.1 Recording rework

Table 5.13 shows the frequency of recording the incidence of rework on construction projects. The findings revealed that 52.6%, representing more than half of the respondents, sometimes recorded the incidence of rework, 24.4% never did, and 23.1%, representing less than a quarter of the respondents, always recorded the incidence of rework.

Table 5.13: Frequency of recording the incidence of rework

Never (%)	Sometimes (%)	Always (%)
24.4	52.6	23.1

5.7.4.2 Direct and indirect costs of rework

Respondents were requested to indicate whether their organisations calculated rework costs. The perception of respondents were determined by using a 5-point Likert scale where 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; and 5 = strongly agree. The findings from Table 5.14 depict that the efficiency of recording rework occurrences was ranked first with a mean score of 3.22; the efficiency of calculating direct cost of rework was ranked second with a mean score of 3.03. These results suggest that respondents tended to be neutral concerning the statements that the system of recording rework occurrences was efficient and that the system of calculating direct cost of rework was efficient. The adverse impact of the cost of rework was ranked third (2.85), implying that respondents tended to disagree that the adverse impact of the cost of rework on profit has not been clearly reported.

Table 5.14: Direct and indirect costs of rework

Statement	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
The system of recording rework occurrences was efficient	78	11.5	11.5	34.6	28.2	14.1	3.22	1.18	1
The system of calculating direct cost of rework was efficient (e.g. additional time, material and labour for covering rework occurrences)	78	11.5	19.2	35.9	21.8	11.5	3.03	1.16	2
The adverse impact of the cost of rework on profit has not been clearly reported	78	9.0	20.5	51.3	15.4	3.8	2.85	0.93	3
The system of calculating indirect cost of rework was efficient (e.g. loss of schedule and productivity, litigation and claims, and low operational efficiency)	78	15.4	17.9	48.7	14.1	3.8	2.73	1.02	4

5.7.4.3 Design-related source of rework cost

Respondents were requested to indicate the extent to which rework costs are attributable to design-related sources on a 5-point Likert scale where 1 = not at all; 2= to least extent; 3= to some extent; 4 = to larger extent; and 5 = to a very large extent. From Table 5.15, it was apparent that changes made at the request of the client had the highest score with a mean of 3.27. This implies that respondents agreed to some extent that design-related rework costs were attributable to changes made at the request of the client. Revisions, modifications and improvements of the design initiated by the contractor or subcontractor were ranked second with a mean score of 2.71 and changes made at the request of the contractor during construction was third with a mean score of 2.60. Since the means were hovering around 2 and 3 this indicates that, revisions, modifications and improvements of the design initiated by the contractor or subcontractor and changes made at the request of the contractor during construction contributed to design-related rework cost to at least an extent.

Table 5.15: Design-related source of rework cost

Design-related sources	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Changes made at the request of the client	77	2.6	16.9	40.3	31.2	9.1	3.27	0.94	1
Revisions, modifications and improvements of the design initiated by the contractor or subcontractor	77	6.5	29.9	51.9	9.1	2.6	2.71	0.83	2
Changes made at the request of the contractor during construction	77	14.3	23.4	50.6	10.4	1.3	2.61	0.91	3
Omission of items from the contract documentation	77	18.2	40.3	28.6	9.1	3.9	2.40	1.02	4
Errors made in the contract documentation	77	20.8	37.7	29.9	9.1	2.6	2.35	1.00	5
Changes initiated by an end-user/municipality	77	29.9	31.2	20.8	13.0	5.2	2.32	1.19	6

5.7.4.4 Construction-related source of rework cost

Respondents were requested to indicate the extent to which rework costs are attributable to construction-related sources. It was evident in Table 5.16 that changes in construction methods due to site conditions was ranked first (M=2.88) followed by changes initiated by the client or an occupier after some work had been undertaken on-site (2.81) and damages caused by a subcontractor (2.69). These results indicate that respondents agreed to at least an extent that changes in construction methods due to site conditions, changes initiated by the client or an occupier after some work had been undertaken on-site and damages caused by a subcontractor were factors attributable to construction-related source of rework cost.

Table 5.16: construction-related source of rework cost

Construction-related sources	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Changes in construction methods due to site conditions	77	7.8	29.9	37.7	15.6	9.1	2.88	1.06	1
Changes initiated by the client or an occupier after some work had been undertaken on-site	77	13.0	23.4	39.0	19.5	5.2	2.81	1.06	2
Damages caused by a subcontractor	77	18.2	26.0	29.9	20.8	5.2	2.69	1.15	3
Errors due to inappropriate construction methods	76	17.1	28.9	30.3	17.1	6.6	2.67	1.15	4
Omission of some activity or task	76	17.1	32.9	28.9	17.1	3.9	2.58	1.09	5
Changes initiated by the client or an occupier when a product or process had been completed	77	24.7	26.0	26.0	15.6	7.8	2.56	1.24	6
Changes in the method of construction to improve constructability	77	23.4	27.3	37.7	6.5	5.2	2.43	1.08	7
Changes initiated by a contractor to improve quality	77	28.6	31.2	24.7	10.4	5.2	2.32	1.15	8

5.7.4.5 Cost sources

Respondents were requested to indicate which areas of cost increased as a result of rework. The findings, according to Table 5.17, revealed that the most ranked area of cost increase as a result of rework was preliminaries with a mean score of 2.91; the second area was overtime cost with a mean score of 2.43; and third was supervision with a mean score of 2.36. Respondents suggested preliminaries, overtime costs and supervision cost contributed to at least an extent of rework cost.

Table 5.17: Cost-sources

Cost-sources	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Preliminaries (eg. scaffolding, carnage)	75	24.0	13.3	26.7	20.0	16.0	2.91	1.40	1
Overtime costs	75	28.0	28.0	24.0	13.3	6.7	2.43	1.22	2
Supervision	75	32.0	28.0	20.0	12.0	8.0	2.36	1.27	3
Fees for design consultants	74	32.4	29.7	27.0	6.8	4.1	2.20	1.10	4
Disruption costs	75	54.7	17.3	12.0	9.3	6.7	1.96	1.29	5
Acceleration costs	75	52.0	29.3	8.0	9.3	1.3	1.79	1.03	6

5.7.4.6 Rework costs

The questionnaire survey asked respondents to provide an estimate of the percentage of the project's original contract sum of the direct and indirect costs of rework that occurred in the project selected. Table 5.18 identifies the mean and standard deviation of the direct, indirect and total rework costs for the 78 construction projects. The direct rework costs indicated by respondents ranged from zero percent (0%) to twenty percent (20%), with a mean of 2.93% and standard deviation of 3.87%. While indirect rework costs ranged from zero percent (0%) to sixty percent (60%), the mean was 2.20% and standard deviation was 7.51%. Clearly, respondents suggest that the direct rework costs (M = 2.93) are higher than the indirect rework costs (M = 2.20) for the projects selected. The total rework costs were calculated by adding the direct and indirect estimates provided by the respondents. The data indicates that the total rework costs ranged from zero percent (0%) to seventy five percent (75%), the mean at 5.12% and standard deviation of 9.94%. Evidently, the total costs of rework vary considerably among projects. The degree of variability is akin to a study undertaken by Love (2002a) where some respondents reported rework costs to be less than 1% of a project's original contract value, while others reported them to be as high as 80%. Love (2002a) argued that the degree of variability in the estimates specified by the respondents suggests that many respondents may be unsure about the actual costs of rework incurred in the projects.

Table 5.18: Rework costs

Rework costs	N	Minimum (%)	Mean (%)	Maximum (%)	Standard Deviation (%)
Direct rework costs as percentage of original contract value	78	0.00	2.93	20.00	3.87
Indirect rework costs as percentage of original contract value	78	0.00	2.20	60.00	7.51
Total rework costs	78	0.00	5.12	75.00	9.94

5.7.4.6.1 Rework costs versus project types

Table 5.19 depicts the direct and indirect costs of rework for the various project types sampled. The direct rework costs suggested by respondents for new build projects ranged from zero percent (0%) to twenty percent (20%), with a mean of 2.77% and standard deviation of 3.9%. Comparatively, direct rework costs indicated by respondents for refurbishment or renovation projects ranged between 0%and 11% with a mean score of 3.65% and standard deviation 3.88%. Relative to the indirect rework costs for new build projects, it ranged from zero percent (0%) to sixty percent (60%) with the mean of 2.12% and standard deviation of 8.44%. The indirect rework costs for refurbishment or renovation projects ranged from 0% to 20%, with a mean score of 2.63% and standard deviation of 4.70%. The total costs of rework for both project types was established by adding the direct and indirect costs; the mean value for new build and refurbishment or renovation projects was 4.89 and 6.28 respectively (see Table 5.20). By comparing the means, these results indicate that both the direct and indirect costs and total costs of rework for refurbishment or renovation projects are comparatively higher than to new build projects.

Table 5.19: Direct and Indirect rework costs versus project type

Project type	Direct rework costs						Indirect rework costs				
	N	Min. (%)	Mean (%)	Max (%)	Std Dev (%)	Std Error (%)	Min. (%)	Mean (%)	Max. (%)	Std Dev (%)	Std Error (%)
New Build	56	0.00	2.77	20.00	3.90	0.52	0.00	2.12	60.00	8.44	1.13
Refurbishment/ Renovation	20	0.00	3.65	11.00	3.88	0.87	0.00	2.63	20.00	4.70	1.05
Total	76	0.00	2.93	20.00	3.87	0.44	0.00	2.20	60.00	7.51	0.85

Table 5.20: Total rework cost for projects types

Project type	N	Minimum (%)	Mean (%)	Maximum (%)	Std. Dev (%)	Std Error (%)
New build	56	0.00	4.89	75.00	10.79	1.44
Refurbishment/Renovation	20	0.00	6.28	30.00	7.67	1.71

5.7.4.6.2 Rework costs versus procurement methods

Table 5.21 identifies the direct and indirect rework costs for each procurement method. The direct rework costs suggested by respondents for traditional lump sum method ranged from 0% to 15%, with a mean of 1.88% and standard deviation of 4.13%. On the other hand, the indirect costs for traditional lump sum method ranged from 0% to 60% with a mean score of 4.85% and standard deviation of 16.58%. For traditional with provisional quantities, the direct costs ranged from 0% to 20% (M = 2.83%, SD = 3.78%) and the indirect costs ranged between 0% and 20% (M = 1.28%, SD = 3.18%). Regarding design and manage method, the direct rework costs ranged from 0% to 10% (M = 4.08%, SD = 4.20%), with its indirect rework costs ranging from 0% to 2% (M = 0.75%, SD = 0.99%).

Consequently, procurement methods were reclassified into traditional and non-traditional. Table 5.22 presents the mean and standard deviation for total rework costs for traditional and non-traditional methods, revealing that traditional methods (mean = 4.84%) are prone to higher rework costs compared to non-traditional methods (mean = 4.14%).

Table 5.21: Direct and indirect rework costs for procurement methods used

Procurement method	**Direct rework costs**						**Indirect rework costs**				
	N	Min. (%)	Mean (%)	Max. (%)	Std Dev (%)	Std Error (%)	Min. (%)	Mean (%)	Max. (%)	Std Dev (%)	Std Error (%)
Traditional lump sum	13	0.00	1.88	15.00	4.13	1.15	0.00	4.85	60.00	16.58	4.60
Traditional with provisional quantities	45	0.00	2.83	20.00	3.78	0.56	0.00	1.28	20.00	3.18	0.47
Design and manage	6	0.00	4.08	10.00	4.20	1.71	0.00	0.75	2.00	0.99	0.40
Construction management	4	0.00	1.75	7.00	3.50	1.75	0.00	0.00	.00	0.00	0.00
Design and build	3	1.50	2.67	4.00	1.26	0.73	0.50	1.00	1.50	0.50	0.29
Turnkey	1	8.00	8.00	8.00	-	-	3.00	3.00	3.00	-	-
Tender full of Bill of quantities	1	3.00	3.00	3.00	-	-	10.00	10.0 0	10.00	-	-
Total	73	0.00	2.93	20.00	3.87	0.44	0.00	2.20	60.00	7.51	0.85

Table 5.22: Total rework cost for traditional and non-traditional method

Procurement method	N	Minimum (%)	Mean (%)	Maximum (%)	Std. Dev (%)	Std Error (%)
Traditional	59	0.00	4.84	75.00	10.56	1.37
Non-traditional	14	0.00	4.14	11.00	4.16	1.11

5.7.5 Rework containment strategies

5.7.5.1 Design management strategy

This section assesses respondents' perceptions with regard to design management strategies that could be implemented to reduce the occurrence of rework during construction. A 5 Likert scale question where 1 = ineffective; 2 = least effective; 3 = quite effective; 4 = effective and 5 = highly effective was used. Table 5.23 shows that the most frequently ranked design management strategy acknowledged to be effective in reducing the incidence of rework was team building (3.48) followed by involvement of subcontractor and suppliers during design with a mean value of 3.30 and design for construction (e.g. standardised components) with a mean score of 3.26. In view of the fact that the means for the highly ranked strategies were between 3 and 4, it is clear that design management strategies implemented were quite effective.

Table 5.23: Design management strategy

Design Management	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean (%)	Std Dev	Rank
Team building	60	1.7	3.3	50.0	35.0	10.0	3.48	0.79	1
Involvement of subcontractor/suppliers during design	54	5.6	11.1	40.7	33.3	9.3	3.30	0.98	2
Design for construction (eg standardised components)	53	1.9	24.5	35.8	20.8	17.0	3.26	1.08	3
Value management	67	1.5	20.9	41.8	26.9	9.0	3.21	0.93	4
Constructability analysis	50	8.0	16.0	50.0	22.0	4.0	2.98	0.94	5
Computer visualisation techniques	51	13.7	27.5	29.4	11.8	17.6	2.92	1.29	6
Design scope freezing	36	19.4	33.3	19.4	16.7	11.1	2.67	1.29	7

5.7.5.2 Site management strategy

Respondents were required to indicate the level of effectiveness of site management strategies. Findings from Table 5.24 reveal that involvement of subcontractors during construction was ranked first by respondents, with a mean value was 3.74, implying that this strategy was effective for reducing the incidence of rework on site. Quality control was ranked second with a mean score of 3.42 and site quality management system was ranked third with a mean score of 3.39. This indicates that these two site management strategies were quite effective in reducing the incidence of rework.

Table 5.24: Site management strategy

Site management	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std Dev	Rank
Involvement of subcontractors during construction	73	0.0	1.4	39.7	42.5	16.4	3.74	0.75	1
Quality control	73	0.0	2.7	58.9	31.5	6.8	3.42	0.67	2
Site quality management system	67	1.5	3.0	61.2	23.9	10.4	3.39	0.78	3
Quality audits	64	3.1	17.2	51.6	26.6	1.6	3.06	0.79	4
Value engineering	61	1.6	26.2	47.5	21.3	3.3	2.98	0.83	5

5.8 Testing of hypotheses

H1: The causes of rework do not differ significantly between various project types.

It was evident from the analysis of the questionnaire survey and case study that reworks are a common occurrence in construction projects. The T-tests in Table 5.25, 5.26, 5.27 and 5.28 were used to determine if the causes of rework significantly differ between various project types. Levene's test of homogeneity of variances was not violated for client-related rework (0.471), design-related rework (0.267) and site management- related rework (0.313), which indicates that the population variances for each group were approximately equal. On the other hand, Levene's test of homogeneity of variances was violated for subcontractor-related rework (0.011) which indicates that the population variances were significantly different. Table 5.25 shows that the T value is 0.410 and at 74 degrees of freedom the significance (0.683) is greater than 0.05 which indicates that there is no significant difference between project types and client-related rework. From Table 5.26, it is evident that the T value is 0.273 and at 74 degrees of freedom the significance (0.786) is greater than 0.05 which indicates that there is no significant difference between project types and design-related rework. From Table 5.27, the T value is 1.170 and at 74 degrees of freedom the significance (0.246) is greater than 0.05 which indicates that there is no significant difference between project types and site management-related rework. From Table 5.28, the T value is 1.190 and at 24.751 degrees of freedom the significance (0.245) is greater than 0.05 which indicates that there is no significant difference between project types and subcontractor-related rework. Clearly, the T-test established that the causes of rework do not differ significantly between the projects types. Therefore the hypothesis that the causes of rework do not differ significantly between various project types cannot be rejected.

Table 5.25: *t*-Test for client-related factors and project types

	Levene's Test for Equality of Variances		*t*-test for Equality of Means						
								95% confidence interval of difference	
	F	Sig.	*t*	df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference	Lower	Upper
Equal variances assumed	.525	.471	-.410	74.000	.683	-.081	.196	-.472	.311
Equal variances not assumed			-.434	37.327	.667	-.081	.186	-.457	.296

Table 5.26: *t*-Test for design-related factors and project types

	Levene's Test for Equality of Variances		*t*-test for Equality of Means						
								95% confidence interval of the difference	
	F	Sig.	*t*	df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference	Lower	Upper
Equal variances assumed	1.249	.267	.273	74.000	.786	.044	.162	-.279	.368
Equal variances not assumed			.251	29.057	.804	.044	.177	-.317	.406

Table 5.27: *t*-Test for Site management-related factors and project types

	Levene's Test for Equality of Variances		*t*-test for Equality of Means						
								95% confidence interval of the difference	
	F	Sig.	*t*	df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference	Lower	Upper
Equal variances assumed	1.033	.313	1.170	74.000	.246	.206	.176	-.145	.557
Equal variances not assumed			1.069	28.824	.294	.206	.193	-.188	.601

Table 5.28: *t*-Test for Subcontractor-related factors and project types

	Levene's Test for Equality of Variances		*t*-test for Equality of Means						
								95% confidence interval of the difference	
	F	Sig.	*t*	df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference	Lower	Upper
Equal variances assumed	6.734	.011	1.462	74.000	.148	.266	.182	-.097	.629
Equal variances not assumed			1.190	24.751	.245	.266	.224	-.195	.727

H2: There is correlation between the impact of rework on organisational performance and the causes of rework.

The linear regression was done to establish whether there is a correlation between the impact of rework on organisational performance and the causes of rework. The regression analysis in Table 5.29 revealed that the effects of client-related rework (B=0.064, P=0.634), design-related rework (B=0.306, P=0.107), site management- related rework (B=-0.216, P=0.253) and subcontractor-related rework (B=0.196, P=0.241) are not significantly correlated. Hence, the positive coefficients (B) for client- related, design-related and subcontractor-related rework may imply that the causes of rework are not an important factor in predicting organisational performance. Therefore, the hypothesis that there is a correlation between the impact of rework on organisational performance and causes of rework can be rejected.

Table 5.29: Linear regressions: Correlation between causes of rework and rework impact on organisation

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig
		B	Std. Error	Beta		
1	(Constant)	.767	.633		1.211	.230
	Client-Related Factors	.064	.134	.061	.478	.634
	Design-Related Factors	.306	.187	.235	1.633	.107
	Site Management Factors	-.216	.188	-.184	-1.151	.253
	Subcontractor Factors	.196	.166	.173	1.183	.241

H3: There are correlation between the impact of rework on project performance and the causes of rework.

The linear regression was used to determine whether there is a correlation between the impact of rework on project performance and the causes of rework. The regression analysis in Table 5.30 revealed that the effect of client-related rework (B=0.291, P= 0.047) is significantly correlated; consequently, the positive coefficient indicates that client-related rework is not an important factor in predicting project performance. The effect of design-related rework (B=-0.049, P=0.809) is not significant; nevertheless, the negative coefficient indicates that increase in design-related rework leads to poor project performance. Also the effect of site management-related rework (B=-0.118, P=0.560) is not significant, but the negative coefficient indicates that the higher the causes of rework as a result of site management factors, the lower the project performance. The effect of subcontractor-related rework (B=0.151, P=0.398) is not significant; besides, the positive coefficient indicates that subcontractor-related rework is not an important factor in predicting project performance. Therefore the hypothesis that there is a correlation between the impact of rework on project performance and causes of rework can neither be accepted nor rejected.

Table 5.30: Linear regressions: Correlation between causes of rework and rework impact on project performance

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig
		B	Std. Error	Beta		
1	(Constant)	1.519	.681		2.231	.029
	Client-Related Factors	.291	.144	.257	2.018	.047
	Design-Related Factors	-.049	.202	-.035	-.242	.809
	Site Management Factors	-.118	.202	-.094	-.585	.560
	Subcontractor Factors	.151	.178	.125	.851	.398

H4: The perception on the implementation of systems for measuring rework to improve the overall cost performance in a construction project do not differ among construction participants.

It was found that respondents expressed feelings of neutrality and disagreement relative to the implementation of systems for capturing rework. The ANOVA test was performed to determine whether the perceptions on the implementation of systems for measuring rework differ among construction participants. The test in Table 5.31 reveals no significant difference between construction participants' perceptions for recording rework (p=0.244), calculating indirect cost of rework (p=0.744), calculating direct cost of rework (p=0.070) and the adverse impact of rework on cost (p=0.267). Therefore, the hypothesis that perception on the implementation of systems for measuring rework to improve the overall cost performance in a construction project does not differ among construction participants cannot be rejected.

Table 5.31: ANOVA: Implementation of systems for measuring rework and construction participants

		Degrees of Freedom	F	Sig
Recording rework occurrences	Between groups Within groups Total	4 72 76	1.395	0.244
Calculating indirect cost of rework	Between groups Within groups Total	4 72 76	0.489	0.744
Calculating direct cost of rework	Between groups Within groups Total	4 72 76	2.269	0.070
Adverse impact of the cost of rework	Between groups Within groups Total	4 72 76	1.330	0.267

H5: There is a significant difference between project type and total rework costs.

The findings revealed that the total cost of rework for new build project and refurbishment/renovation projects was 4.89% and 6.28% respectively. The ANOVA test was used to determine if there was a statistically significant difference between the means of total rework costs for the different project types. Levene's test of homogeneity of variances for both direct and indirect rework cost was not violated. From Table 5.32, we see that the significance is 0.993, which is greater than 0.05, indicating that the two variances for each project type are not significantly different; that is, the two variances are approximately equal. The ANOVA test in Table 5.33 revealed no significant difference between project types for direct rework costs $F(2,75)=0.958$, $p>0.05$, indirect rework costs $F(2,75)=0.117$, $p>0.05$, and total rework costs, $F(2,75)=0.406, p>0.05$. Therefore the hypothesis that there is a significant difference between project types and total rework costs is rejected.

Table 5.32: Levene and *t*-Test for project type and total rework costs

	Levene's Test for Equality of Variances		*t*-test for Equality of Means						
								95% confidence interval of the difference	
	F	Sig.	*t*	Df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference	Lower	Upper
Equal variances assumed	.000	.993	-.527	74.000	.600	-1.38464	2.62603	-6.61711	3.84783
Equal variances not assumed			-.618	47.214	.540	-1.38464	2.24031	-5.89103	3.12175

Table 5.33: Analysis of variance (ANOVA): difference between project type and rework costs

Direct rework cost				Indirect rework cost		Total rework cost	
Source	Df	F	Sig. (Pr > F)	F	Sig. (Pr > F)	F	Sig. (Pr > F)
Model	2	.958	.388	0.117	0.889	0.406	0.668
Error	75						
Corrected total	77						

H6: There is no significant difference between various procurement methods and total rework costs.

The ANOVA test was used to determine if there was a statistically significant difference between the means of total rework costs for varying procurement methods. The ANOVA test in Table 5.34 revealed no significant differences between various procurement methods and total rework costs, F (7, 70) =0.575, p>0.05. The hypothesis that rework costs do not vary significantly with various procurement methods can therefore not be rejected.

Table 5.34: Analysis of variance (ANOVA) Rework costs and Procurement methods

Source	Degrees of Freedom	F	Pr>F
Model	7	0.575	0.774
Error	70		
Corrected total	77		

5.9 Discussion of findings

This section discusses the findings of the study, in particular the causes, impact, cost implications and reduction and containment strategies for rework.

5.9.1 Causes of rework

The literature revealed that the root causes of rework can be categorised into different groups such as client-related, design-related and contractor-related factors including site management and subcontractor factors. Therefore, the causes of rework were examined based on the above. The findings of the study revealed that poor communication between design consultants and clients was the major factor contributing to client-related rework. This may imply that there is not much interaction between clients and the design team consultants to ensure that clients' ideas are communicated properly; as a result, rework emanates right from the initiation stage, proceeding through an incubation system, and manifesting itself during the implementation stage. Moreover, in the case of design-related factors, the predominant factor suggested by respondents was changes made at the request of the client. This may imply that most clients lack experience with regard to the design process and because of this their ideas might not be feasible during the design. This claim is supported by Palaneeswaran (2006) who suggested that lack of experience and knowledge of design and construction processes on the part of the client contributed to rework.

Relative to site management-related factors, respondents identified setting out errors as the major factor contributing to rework. The initial exploratory case study established that setting out errors were attributable to the sequential nature of the supply chain which resulted in poor coordination and integration between site management team members. This was exacerbated by misinterpretation of the working drawings due to inexperience and the inability to communicate effectively with subcontractors. It was reported by respondents that low-skilled labour employed by subcontractors resulted in rework. Implicitly, the human resource support systems such as education, training, motivation, and improved skill level provided by employees' organisations so that they can perform their jobs more effectively and productively is lacking. Besides, skill shortage is one of the crucial problems facing the South African construction industry. This is supported by Loxton (2004) who reported that the South African construction industry is under pressure due to a combination of factors, one of which is skills shortages. The T-test was used in this instance to test for differences between the causes of rework and project types; at the 95% confidence level, it was revealed that causes of rework do not differ significantly between project types.

5.9.2 Impact of rework on organisation and project performance

The literature confirmed that rework in construction projects has an adverse impact on overall project performance. It was vital, therefore, to investigate the impact of rework on organisation and project performance in construction projects. The study revealed that respondents tended neither to agree nor disagree that cost overrun, time overrun and design team dissatisfaction impacted on project performance. Love (2002b), in a study conducted in Australia to determine the indirect consequences of rework, identified reduced profit, and diminished professional image, inter-organisational conflict, and de-motivation of workers as effects of rework. However, the South African findings disclosed feelings of disagreement and neutrality on the part of respondents that reduced profits, de-motivation of workers and inter-organisational conflict impacted on the performance of organisations as a result of rework.

The linear regression was used to determine the extent to which there is a relationship between organisational and overall project performance and the causes of rework. The regression analysis revealed no significant correlation ($p>0.05$) between the causes of rework (that is client-related, design-related, site management-related and subcontractor-related source of rework) and the impact of rework on organisational performance. Furthermore, the linear regression divulges that there is no significant correlation ($p>0.05$) between the impact of rework on project performance and design- related, site management and subcontractor-related rework. However, there was a significant correlation ($p<0.05$) between client-related sources of rework and the impact of rework on project performance.

5.9.3 Rework costs

It was found that only a minority recorded the incidence of rework as respondents tended to be neutral with regards to the necessity and efficiency of recording rework occurrences. The study also found that respondents remained neutral with regards to measuring the direct cost of rework. Furthermore, it was established that respondents expressed their disagreement relative to the efficiency of calculating their indirect costs of rework. This suggests that the majority of respondents do not appreciate the economic benefits of measuring rework costs, especially the indirect cost. Love (2002b) supported these findings by reporting that there is little known about the indirect consequences of rework in construction projects, especially the financial consequences. Besides, there has been limited research seeking to determine the indirect costs of rework (Love, 2002b). The estimate as a percentage of the project's original contract sum provided by respondents indicated that the direct rework cost were higher than indirect rework costs for the projects selected. Respondents estimated the direct costs of rework to have a mean of 2.93% as opposed to indirect costs of rework with a mean of 2.2%. Equation 1 was used to determine the total rework costs that were incurred in the sampled projects. The mean total rework cost as a percentage of the original contract value was discovered to be 5.12%. Moreover, the total costs of rework were found to vary considerably among projects. Some respondents reported rework costs to be 0% of a project's original contract value, while others have reported the costs to be as high as 75%.

$TR_c = \Sigma\, Dr_c + \Sigma\, Ind_c$………………………………………………………….. [Eq.1]

where,

TR_c = Total rework cost (% of contract value at award)

Dr_c = Direct rework cost expressed (% of contract value at award)

Ind_c = Indirect rework cost expressed (% of contract value at award)

Adopted from: Love (2002a)

It was evident from the findings presented above that refurbishment/renovation projects experienced higher rework cost compared to new build projects. The mean values for new build and refurbishment/renovation projects were 4.89% and 6.28% respectively. This finding corresponds with previous research undertaken by Love and Wyatt (1997) which suggested that refurbishment/renovation projects are considered prone to higher rework costs than new build projects because of the degree of uncertainty and complexity associated with the building work to be undertaken. The analysis of variance (ANOVA) test was used to determine if there was a statistically significant difference between the means of total rework costs for the different project types. The ANOVA test revealed that rework costs do not significantly vary among project types. Apparently, the study revealed that traditional procurement methods (mean =4.84%) experienced higher rework costs compared to non-traditional methods (mean=4.14%). The ANOVA test was used to determine if there was a statistically significant difference between the means of total rework costs for varying procurement methods. The ANOVA test revealed no significant differences between various procurement methods selected by respondents and total rework costs.

5.9.4 Rework containment strategy

Love, Edwards and Smith (2005) argued that the incidence of rework in construction is system orientated. And until rework is eliminated, conscientious attention must be given to preventing it. Also, organisations should create the necessary energies to improve the processes affecting rework. Love, Smith and Li (1999) suggested that metrics for rework need to be established so that a process of benchmarking can be initiated. Then, rework can be significantly reduced and the overall performance and output of a project improved. Oyewobi and Ogunsemi (2010) also argued that the essence of contract management cannot be waved away if rework occurrence has to be reduced to a considerable level. This is simply because good contract management will increase efficiencies, minimise waste, enhance cost control mechanisms and improve overall management of construction sites. The findings reveal that respondents also suggested that to reduce or prevent rework in construction projects that design manage strategies—team building, involvement of subcontractors/supplies during design, and design for construction such as standardised components—should be implemented. In the case of site management strategies, respondents suggested involvement of subcontractors during construction. Indeed, involvement of subcontractors during the planning and construction stage will lead to increasingly effective communication between subcontractors and their main contractors. In addition, the involvement of subcontractors will ensure proper coordination of site activities and will eventually minimise the occurrence of rework. The study also revealed that the implementation of quality control will minimise the occurrence of rework on site. This finding is supported by the literature that construction projects with good quality control will experience less rework. Respondents also suggested the implementation of site quality management systems as another way of minimising the incidence of rework. This finding concurs with Alwi, Hampson and Mohamed (2001) who suggested the need for quality supervision as one of the site quality management systems in order to reduce rework during construction. Alwi *et al* (2001) emphasised that the causes of rework are generated during the construction process; therefore, supervisors need to be more proactive in discovering these causes. Love, Edwards and Smith (2005) also attested that rework may be predominately prevented through the effective implementation of quality management tools such as quality function deployment, failure mode effect analysis, statistical process control, poka-yoka and taguchi methods for process improvement.

Love and Sing (2011) suggested that foresight and anticipation can enable strategies to be put in place to minimise the impact of rework on project cost and schedule. So in order to minimise rework occurrences, it is imperative to predict its occurrences *prior* to construction activities on site. Rogge, Cogliser, Alaman and McCormack (2001) developed the "*Field Rework Index",* (FRI), to determine the risk of rework before construction commenced so that corrective action to lower its risk levels could be undertaken. Love and Sing (2011) suggested that to manage and control the risk of rework, it is necessary to determine its probability of occurrence to construction.

5.9.4.1 Probability of rework occurrence

Building upon research reported in Love and Sing (2011), the probability of rework occurring during construction from contract award is determined. Table 5.35 presents the descriptive statistics for the total rework costs used in determining the probability of rework in the sampled project.

Table 5.35: Descriptive statistics for total rework costs

Statistic	Value	Percentile	Value
Sample Size	78	Min	0
Range	75	5%	0
Mean	5.1209	10%	0
Variance	98.722	25% (Q1)	0
Std. Deviation	9.9359	50% (Median)	2.5
Coef. of Variation	1.9403	75% (Q3)	6.625
Std. Error	1.125	90%	11
Skewness	4.9999	95%	20.25
Excess Kurtosis	32.194	Max	75

The following steps were adopted to determine the probability of rework. First and foremost, the Probability Density Functions (PDF) were developed using "*EasyFit Professional 5.5".* A PDF for a continuous distribution can be expressed in terms of an integral between two points:

$$\int_a^b f(x)dx = P(a \le X \le b) \text{ .... [Eq.2]}$$

F(x) = Probability density function for the continuous random variable

a to *b* = interval between two points, if the interval is made infinitesimally small, *a* approaches *b* and *P(a ≤ X≤ b)* approaches zero.

A Cumulative Distribution Functions (CDF) was also produced. For theoretical continuous distributions, the CDF is expressed as a curve and denoted by:

$$F(x) = \int_{-\infty}^{x} f(t)dt \text{ .... [Eq.3]}$$

$F(x)$ = cumulative distribution function for the random variable *x*

$\int_{-\infty}^{x} f(t)dt$ = integration of the probability density function *f(t)* of continuous random variable *x*.

The empirical CDF, which is displayed as a stepped discontinuous line and dependent on the number of bins, is represented by:

$$F_n(x) = \frac{1}{n} \cdot \text{[Number of observations} \leq x] \text{.. [Eq.4]}$$

where,

n = the sample size, that is the maximum value used in determining the probability of rework.

The 'best fit' probability distribution was examined using the 'Goodness of Fit' tests: *Kolmogorov-Smirnov* and *Anderson-Darling (Equation 5 and 6).*

- *Kolmogorov-Smirnov statistic (D)*: Based on the largest vertical difference between the theoretical and empirical CDF:

$$D = \max_{1 \leq i \leq n}\left(F(x_i) - \frac{i-1}{n}, \frac{i}{n} - F(x_i) \right) \text{.. [Eq.5]}$$

- *Anderson-Darling statistic (A^2)*: A general test to compare the fit of an observed CDF to an expected CDF. The test provides more weight to distributions tails than the *Kolmogorov-Smirnov* test. The Anderson-Darling statistic is defined as:

$$A^2 = -n - \frac{1}{n}\sum_{i=1}^{n}(2i-1)\cdot\left[InF(x_i) + In\left(1 - F(x_{n-i+1})\right)\right] \text{.......................... [Eq.6]}$$

where,

n = the sample size, that is the maximum value used in determining the probability of rework

i = minimum value used in determining the probability of rework

In = natural logarithm

The results of the 'Goodness of Fit' tests in Table 5.36 revealed that *General Pareto* distribution provided the best fit for the dataset for total rework costs. A Generalised Pareto is a skewed and heavy-tailed distribution. It is similar to an exponential distribution and is typically used to modify the tails of other distributions. It is used to describe the full range of the data in order to obtain a more complex distribution.

Table 5.36: 'Goodness of Fit Test' for total reworks cost

Kolmogorov-Smirnov					
Sample Size 78					
Statistic 0.21225					
P-Value 0.00146					
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.11935	0.13636	0.15147	0.16938	0.18174
Reject?	Yes	Yes	Yes	Yes	Yes
Anderson-Darling					
Sample Size 78					
Statistic 3.7084					
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	Yes	Yes	Yes	Yes	No

The PDF, CDF and distribution parameters (μ, k, σ) for continuous distributions were examined using the estimation method Maximum Likelihood Estimates. From equations 8 and 9 the parameter *k* is a continuous shape parameter, *σ* continuous scale parameter (*σ* > 0) and *μ* the continuous location parameter. The domain for a Pareto distribution is denoted as $\mu \le x < +\infty$ for $k \ge 0$, and $\mu \le x \le -\sigma/k$ for $k < 0$. The PDF is expressed as:

$$F(x) = \begin{cases} \frac{1}{\sigma}\left(1 + k\frac{(x-\mu)}{\sigma}\right)^{-1-1/k} & k \neq 0 \\ \frac{1}{\sigma}\exp\left(-\frac{(x-\mu)}{\sigma}\right) & k = 0 \end{cases}$$

…………………………………………………..[Eq.7]

The CDF is expressed as:

$$F(x) = \begin{cases} 1-\left(1 + k\frac{(x-\mu)}{\sigma}\right)^{-1/k} & k \neq 0 \\ 1-\exp\left(-\frac{(x-\mu)}{\sigma}\right) & k = 0 \end{cases}$$

…………………………………………………..[Eq.8]

F(x)= cumulative distribution function

k = continuous shape parameter,

σ = continuous scale parameter (*σ* > 0)

μ = continuous location parameter.

In Figure 5.6, the parameters for the *General Pareto* for total rework costs were found to be k = 0.407 σ = 3.435, μ = -0.676. Figures 5.5 to 5.7 present the histograms, PDF and CDF for rework costs based upon the calculated distribution parameters. It can be seen in Figure 5.5, for instance, that 81% (63) of all projects experienced total rework costs < 8%.

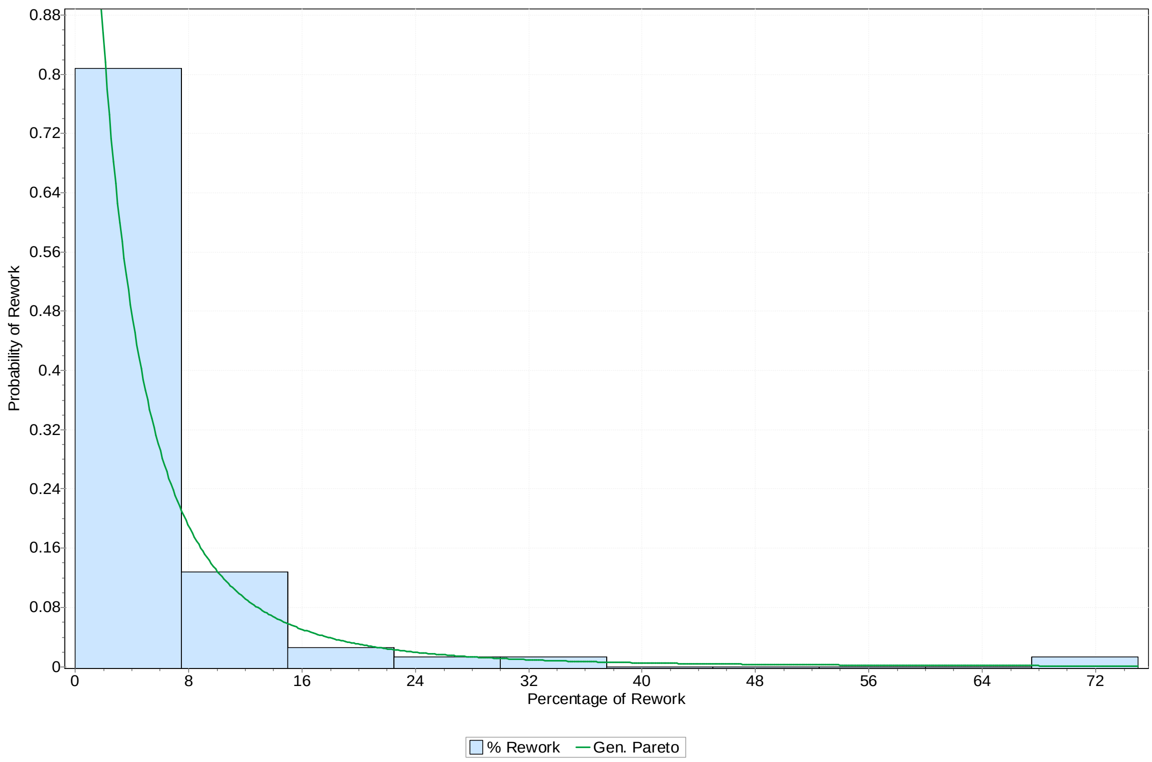

Figure 5.5: Pareto: Histogram of rework

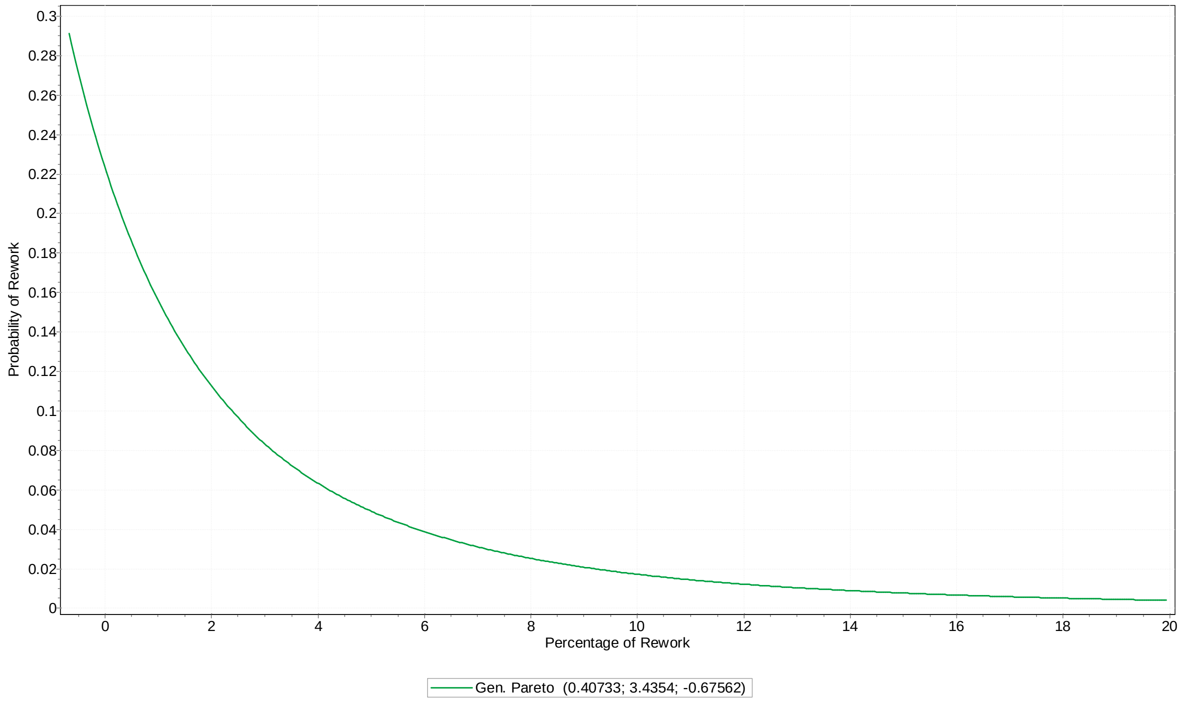

Figure 5.6: Pareto: PDF for total rework costs

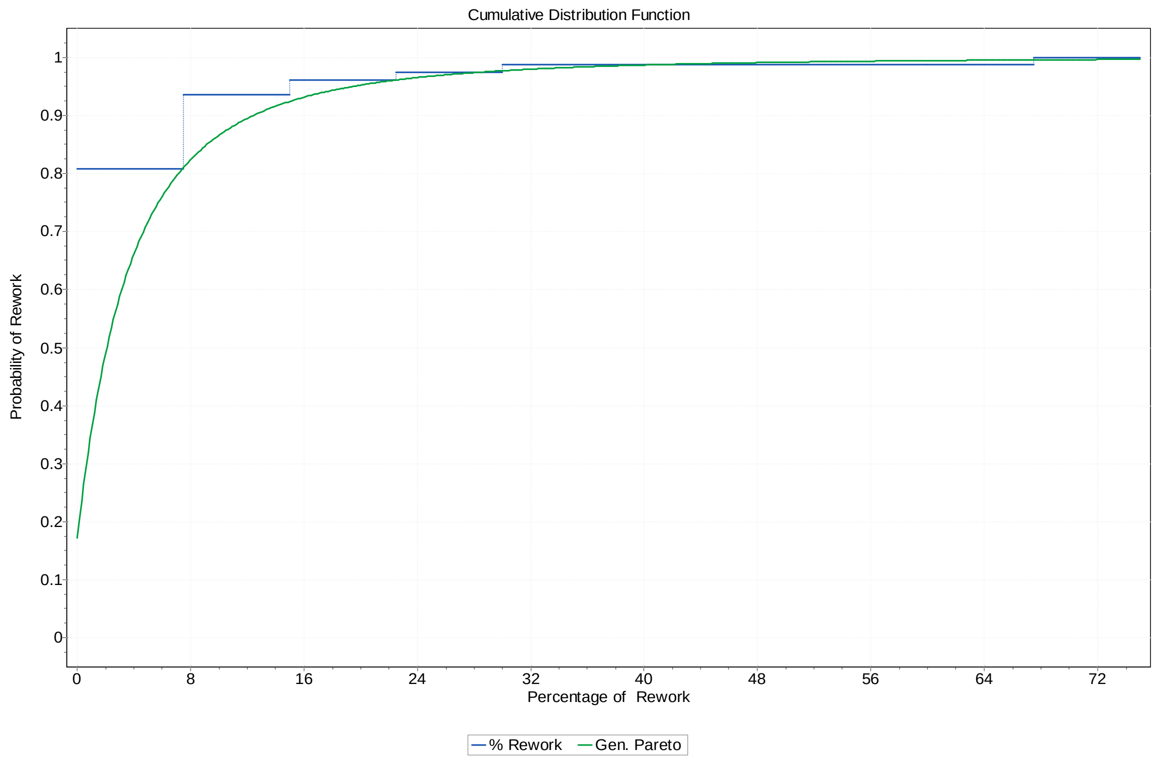

Figure 5.7: Pareto: CDF for total rework costs

Single probability points for rework from 1 to 10% in one percentage increments were calculated as shown in Table 5.37. The probability of experiencing a total rework cost of <10% is 87%. For a mean total rework cost 5.12%, the likelihood that a project exceeds this figure is 76% (P (X < X1) =0.76).

Table 5.37: Probability of rework from 1 up to 10%

Total rework (%)	Probability
< 1	0.36
< 2	0.49
< 3	0.59
< 4	0.66
< 5	0.72
< 6	0.76
< 7	0.80
< 8	0.82
< 9	0.85
< 10	0.87

5.9.4.2 Proposed rework containment and reduction strategy

Figure 5.8 shows a proposed rework containment and reduction flow diagram. A comprehensive discussion of the proposed flow diagram is as follows:

Rework Prediction (RP): rework prediction will assist in discovering what could possibly cause rework during the design and construction phase (rework identification), how likely it is that a major rework would occur, the potential consequences (risk assessment) and the options that are available for preventing and mitigating a major rework (control measures). Rework prediction will also assist in improving operations and productivity and reduce the occurrence of rework.

Adopting control measures for rework: This includes identifying proactive control measures, selecting suitable measures or rejecting inappropriate measures. Selecting or rejecting control measures should be based on the following: justifying the adequacy of control measures, identifying potential common mode failures; and defining performance indicators for the control measures.

Performance Indicators: Performance indicators for control measures in this case relate to standards or target levels of performance such as implementation of quality management systems and learning mechanism to ensure the minimisation of both design and construction-related rework. Performance indicators and corresponding standards will play an essential role in the justification of the 'satisfactoriness' of control measures.

Rework Management System (RMS): This demonstrates a systematic approach to ensure the effective implementation of Rework Management Systems; these systems must be monitored, verified and reviewed to ensure successful implementation.

Rework Report (RR): Control measures should be systematically managed within the rework management system (RMS) and must be presented within the Rework Report. Moreover, the report should include statements on the viability and effectiveness of the range of control measures considered, methods and results of the corresponding rework risk assessments, and the reasons for selection or rejection of control measures. It should also include the Critical Parameters and Performance Indicators for the adopted control measures and a justification of the adequacy of control measures.

Review and Revision: This can be used as lessons learned for knowledge management and for benchmarking with future projects. Control measures must remain valid for the duration of the project life cycle. However, it is unlikely that all control measures will remain valid, due to changes during the design and construction stage and new knowledge about rework and control measure options. Reviews of control measures should be triggered whenever a situation arises that would indicate that control measures are no longer valid or effective.

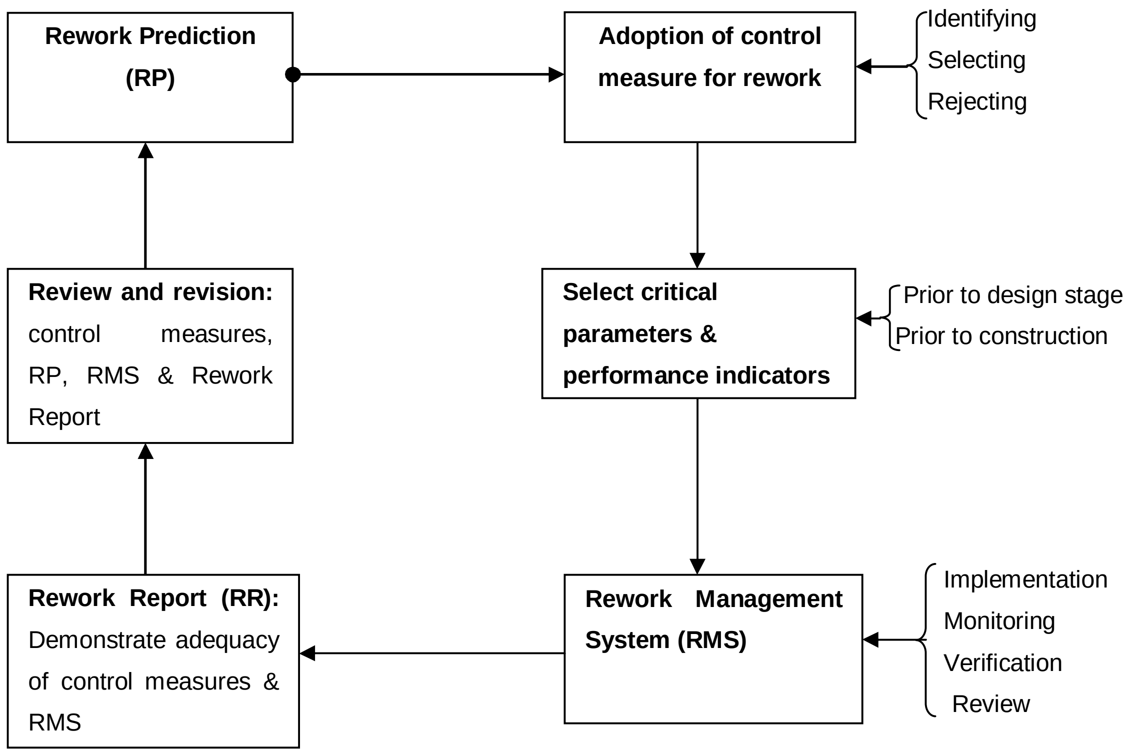

Figure 5.8: Rework containment and reduction flow diagram

The background of this study revealed that the construction industry is characterised by poor organisational management practices during the design and construction stage. Therefore, an improvement in an organisation's management practices and project management strategies, coupled with total commitment to quality of services rendered, would certainly lead to a reduction in the occurrence of reworks.

5.10 Discussion of findings in the context of the literature review

The results of the survey analysis indicate that the root sources of rework in construction projects are the result of poor communication, lack of skills, errors, omissions and changes during both the design and construction phase. This was evident in the literature review. The findings also indicate that rework causes and costs can be influenced, to some extent, by the nature and complexity of the project and the procurement method used in acquiring the project. The research instrument revealed that the cost of undertaken rework in renovation/refurbishment projects was higher compared to new build projects due to the complexity of renovation/refurbishments projects. Likewise, the cost of rework for non-traditional procurement methods varies from traditional procurement methods; this was apparent in the literature review as well. The study established that rework can make a significant detrimental contribution to a project's cost and schedule overrun, which will subsequently result in reduced profit, contractual claims and the tarnishing of the reputation of the organisations involved in a project. These findings are also supported by the literature review.

5.11 Chapter summary

In this chapter, findings emanating from the questionnaire survey were discussed. The analysis was done using the Statistical Package for the Social Sciences (SPSS) program and data were interpreted by means of frequencies and descriptive statistics. The Cronbach's alpha coefficient for scaled questions was 0.9, indicating that the responses to scaled questions were reliable. Concerning the causes of rework, it was found that poor communication with design consultants was a major factor that contributed to client-related rework. In the case of design-related rework, the most predominant factor was change made at the request of the client. Relative to site management related-factors, setting out errors were identified as one of the major factors that contributed to rework. It was evident that low labour skill level used by subcontractors resulted in rework on site. The T-test was used to determine if there were differences between the causes of rework and project types. It was evident that the causes of rework do not differ significantly between project types.

Respondents expressed feelings of disagreement and neutrality about the impact of rework on organisational and project performance. The linear regression was done to establish whether there is a relationship between organisational and overall project performance and the causes of rework. The regression analysis revealed no significant correlation between the causes and the impact of rework on organisational performance. In addition, the linear regression disclosed that there is no significant correlation between the impact of rework on project performance and design-related, site management and subcontractor-related rework. However, there was a significant correlation between client-related sources of rework and the impact of rework on project performance.

The study found that only under a quarter of the respondents kept records of the incidence of rework. Also, respondents remained neutral with regards to measuring its costs (both direct and indirect), and its cost impact. It was also established that the direct rework costs were higher than indirect rework costs for the projects selected. It was apparent that renovation/refurbishment projects were prone to higher rework costs compared to new build projects. The one-way ANOVA test was used to determine the significant differences between various procurement methods and project types and total rework costs. The ANOVA test revealed that rework costs do not vary significantly among project types and various procurement methods.

Respondents suggested that to reduce or prevent rework in construction projects the following design management strategies should be implemented: team building, involvement of subcontractors/supplies during design, and design for construction (e.g. standardised components). In the case of site management strategies, respondents suggested involvement of subcontractors during construction, quality control and site quality management systems.

Furthermore, the probabilistic analysis of rework occurrence was determined in the projects selected; this analysis predicts the occurrence of rework prior to the design and construction stage. The Kolmogorov-Smirnov and Anderson-Darling non-parametric tests were used to determine the 'Goodness of Fit' of the selected probability distributions. A *Generalized Pareto* probability function was found to provide the most excellent distribution fit for rework costs. It was revealed that for a mean total rework cost of 5.12% the likelihood that a project exceeds this figure is 76% ($P (X < X1) = 0.76$).

In addition, a proposed flow chart was developed as a control measure for the reduction of rework occurrence. The main transactions of the proposed flow diagram included the prediction of rework occurrence, the adoption of control measures for rework, the selection of critical parameters and performance indicators, the development of rework management systems, the formulation of rework reports and the review and revision of the report.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter concludes the study, highlights the limitations that were encountered during the survey and makes recommendations based on the findings. In total, six (6) hypotheses were tested against the findings. The conclusions are comprised of the findings from the exploratory study and the analysis of the questionnaire survey. The recommendation section discusses the outcomes and implications of the study.

Aim and objectives

The aim of this study was to determine the underlying causes of rework during construction, and its impact on the overall project performance in order to develop effective prevention strategies.

Specific objectives included:

- To determine the influence different project types have on the causes of rework in construction projects.
- To determine the impact of rework on organisational and project performance.
- To determine the influence various project types have on rework costs (direct and indirect) in construction projects.
- To determine the influence various procurement methods have on total rework costs in construction projects.
- To design and develop rework reduction and containment strategies.

Conclusions

Causes of rework on construction projects

During the initial comparative case study, it was evident that changes made at the request of the client and design team contributed to rework. Love, Edwards and Smith (2005) established that variations during the design process are often captured too late because of the sequential communication structure of supply chains, and the lack of coordination and integration between design team members. This was apparent in the case study, where the lack of coordination among design consultants led to major design-related changes which affected all the design firms involved. This subsequently resulted in changes on site, which affected most of the subcontractors.

Furthermore, setting out errors, due to poor communication and coordination between the main contractor and subcontractors and the lack of skills on the part of the artisans, were identified. In addition, inexperience on the part of the leading hand and trades foremen and their inability to interpret the structural drawing contributed to rework during construction. Similarly, the analysis of the research instrument found that the most predominant source of rework included non-compliance with specification, setting out errors, changes made at the request of the client, poor communication with design consultants and low labour skill levels. Nevertheless, the causes of rework were found not to vary significantly with various project types.

Impact of rework

The analysis of the comparative study revealed that reworks caused inter-organisational conflict that led to dilution in supervision and resulted in the de-motivation of workers. The study also revealed that the incidence of rework increased project cost. This was due to additional materials for rework, subsequent wastage handling, costs for covering rework occurrences and additional labour to rectify erroneous activities. Besides, additional time to rework and related extensions of supervising manpower were also identified, ultimately leading to customer dissatisfaction and reduced profit for contractors.

The analysis of the response of the questionnaire revealed that respondents tended neither to agree, nor disagree, that the cost overrun, time overrun and design team dissatisfaction as a result of rework impacted on project performance. Similarly, respondents expressed sentiments of disagreement and neutrality that reduced profit, de-motivation of workers and inter-organisational conflict all impacted on organisational performance.

Recording rework occurrences and the measurement of its costs

It was apparent in the findings of the questionnaire survey that the majority of the respondents do not always have systems in place for tracking and recording incidences of rework and its cost impact, especially the indirect costs, as they are problematic to accurately calculate. This was also apparent in the case studies, where the respondents revealed they had experienced lots of rework on site. However, there were no mechanisms in place for recording incidences of rework and capturing their costs. This may imply that the causes of rework have not been fully examined in terms of their frequency and cost impact.

The most conclusive finding may be, however, that the economic benefits of recording incidences of rework and quantifying its costs have been overlooked. The total cost of rework for the projects sampled was calculated, and it was found that the total mean cost was 5.12% of the original contract value. Therefore, it can be concluded that rework can make a significant contribution to a project’s cost overrun. Nonetheless, rework costs were found not to vary significantly with project type and various procurement methods used. Thus, the implementation of systems for measuring rework costs will possibly eliminate or reduce the costs of rework and subsequently improve overall cost performance in a construction project.

Rework containment strategies

The study revealed several innovative approaches and management strategies for effectively tackling rework related inefficiencies. In addition, a model has been developed to predict the occurrence of rework so that effective corrective action can be instituted prior to the construction stage. Non-parametric ‘Goodness of Fit’ tests were used to select the best fit probability distribution. A Generalized Pareto probability function was found to provide the best overall distribution fit to calculate the probability of rework. In addition, the Generalized Pareto probability function provided single probability points for rework ranging from 1% to 10% in one percentage increments.

It was also revealed that, for a mean total rework cost of 5.12%, the likelihood that a project exceeds this figure is 76%. Moreover, a proposed flow diagram was developed as a control measure and to reduce rework occurrences. It can be seen from the diagram that, if project participants are to reduce the impact and improve overall cost and project performance of rework, the reduction of rework during construction projects must be a continuous process. This indicates that the more the industry continues to create awareness about the root causes and what constitutes rework, coupled with a systematic approach and structured tracking mechanisms, the more effective strategies can be developed to eliminate this problematic waste.

Therefore, the endemic of rework occurrences, as well as their impacting influence on performance and productivity aspects as suggested by Palaneeswaran (2006), should not be viewed as inevitable. It can therefore be concluded that rework can be substantially decreased by developing adequate awareness as well as structured systems for its management.

Limitations

The literature review found that limited research, relative to the causes and impact of rework, has been conducted in the South African construction industry. Previous studies have focused on defects, reworks and quality management issues in the industry. This study was limited to the Cape Peninsula area in the Western Cape province of South Africa. One of the biggest challenges faced during the research was to get respondents to participate in the study. For example, during the case studies, the respondents were not willing to provide access to information regarding rework costs. It was also difficult to get respondents to complete the questionnaire, as some were not interested in taking part of the survey at all. Also, some were not interested, given that they have no experience with regards to what constitutes rework and what does not. Though an effort was made to ensure that the majority completed and returned the questionnaires, all attempts made to follow-up—visiting offices in person, making telephone calls and sending reminders via emails—proved futile.

For this study, the definition of rework was limited to the following: design errors, changes that affect construction activities, constructability errors, additional or missing scope due to designer or constructor errors and on-site fabrication errors that affect construction activities. The questionnaire survey was structured to address these specific occurrences. Relative to contractors, questionnaires were distributed to construction firms who are in the general building category with a grade ranging from 3 to 9, and are registered and in good standing with the Construction Industry Development Board (CIDB).

Recommendations

Improper differentiation between terms such as quality failure, defects and error with rework has led to inaccurate and incomplete measurements for rework, and possibly inappropriate strategies for reducing its occurrence (Sommerville, 2007). Rework has become the norm and as such it has become inevitable and acceptable in the construction industry. For instance, Atkinson (1998) sees that “making occasional mistakes” is a view accepted by others. Likewise, Love (2002a), Love, Smith and Li (1999) and Josephson, Larson & Li (2002) see rework as endemic in the overall construction process, a view hardly conducive to understanding and eradicating the problem. Therefore, rework reduction and containment strategies can be developed only if a clear distinction is made between what constitutes rework and what does not. Besides this, the industry must change its mindset that rework is inevitable. The study proposes a combination of interventions based on the literature reviewed and the findings of the data analysed.

Creating the awareness as to the impact rework can have on project performance is probably the most obvious intervention and the starting point for establishing an in-depth knowledge of the root source of rework. Therefore, the understanding of the causal structure of rework is an immediate issue that consulting firms and contractors need to grapple with, in order to reduce the causes of rework and its impact on construction project performance.

It was evident from the findings that the economic benefits of quantifying the total costs of rework, both direct and indirect, have been overlooked. Besides, it was established that rework can make a significant contribution to a project's cost overrun. Therefore, to decrease the direct and indirect rework costs and improve overall project performance, it is recommended that construction organisations begin to consider and measure them, so that an understanding of their magnitude can be captured. Also, effort needs to be made to improve skills and knowledge; otherwise the loss of reputation, delays and disruptions to construction and loss of profit will become products of rework that arises on-site.

From the findings, respondents suggested that to reduce rework during the design stage the following strategies ought to be implemented: team building, as well as the involvement of subcontractors, suppliers and designers for construction (e.g. standardised components). In the case of site management strategy, respondents suggested involvement of subcontractors during construction, quality control and with site quality management systems. Therefore, studies are needed to establish how both design firms and contactors can be assisted to implement these strategies.

Love and Sing (2011) stated that foresight and anticipation can enable strategies to be put in place to minimise the impact of rework on project cost and schedule. For this reason, construction professionals need to be more proactive in forecasting the occurrence of rework prior to the design and construction stage. This will enable consulting firms and contractors to undertake a quantitative risk assessment prior to the commencement of construction, as suggested by Love and Sing (2011). A proposed rework containment and reduction flow diagram has been developed for this purpose. This can also serve as a starting point for establishing a comprehensive knowledge of how effective control measures and reduction strategies can be developed.

Areas recommended for further research

The literature and the findings of the study revealed that the economic benefits of measuring rework costs, especially the indirect cost, have been overlooked. Furthermore, there has been limited research that has sought to determine the indirect costs of rework. Further investigation into the costs and impact of rework, especially the indirect costs, is needed to ascertain the hidden costs associated with undertaken rework.

While various studies have ensued which seek to suggest rework reduction and containment strategies, rework still persists in the industry. Therefore, further research into alternative solutions to mitigate rework occurrence in construction projects could be beneficial to the industry.

APPENDICES

APPENDIX A – SEMI-STRUCTURED QUESTIONNAIRE FOR THE EXPLORATORY STUDY

Framework of question for contractors

SECTION A: CAUSES OF REWORK

Changes initiated by parties involved

1. Do the changes initiated by the client constitute rework?
2. Do the changes initiated by the design team constitute rework?
3. Do the changes initiated by the contractor constitute rework?

Human resource capability

1. How often do you organise training programmes for your employees?
2. What criteria do you use in employing workers on site, for example skilled and semi-skilled workers?
3. How often do tradesmen/artisans get supervised during site activities?

Quality management issues

1. Is there any quality system in place to check the quality of work on site?
2. Do you ensure that materials selected conform to the contract specification before using them?
3. Do you get approval from the principal agent in case an alternative material is to be used in place of the one specified in the contract documents?

Audit of site instructions book

1. Does this site instruction constitute rework or not?
2. What was the work implication associated with this site instruction?

SECTION B: IMPACT OF REWORK ON COST AND SCHEDULE

1. Has the client/end-user expressed dissatisfaction about the progress and quality of work on site due to rework?
2. Have any of the consultants expressed dissatisfaction about the progress and standard of work on site as a result of rework?
3. Has there been any dissatisfaction on the part of the contractor due to rework?
4. Is there any litigation between parties involved on this project as a result of rework?
5. Has rework affected the project schedule?
6. Are there extensions of time claims on the part of the contractor as a result of rework?
7. Has rework led to poor morale of workers on site?
8. Has rework led to dilution of supervision on site?
9. Has there been any conflict/dispute on site due to rework?

Audit of cash flow projections and bill of quantities

1. Are there any overtime costs incurred as a result of rework?
2. Have there been any disruption costs incurred as a result of rework?
3. Has there been any increase in preliminaries as a result of keeping scaffolding and plants on site due to rework?

Framework of questions for consultants

Human resource capability

1. How often do you organise training programmes for your employees?
2. What criteria do you use in employing workers?

Quality management issues

1. Do you undertake design verifications, reviews and audits prior to issuing out the drawings?
2. Is there any third party involvement to audit and review the design and documentation prior to the tendering stage?
3. Do you perform design activities such as architectural, mechanical and structural engineering concurrently?

APPENDIX B – QUESTIONNAIRE FOR THE MAIN STUDY

Cape Peninsula University of Technology

Department of the Built Environment

P. O. Box 1906 Bellville 7535 ABCBuilding, First floor,

Symphony Way (off Modderdam Road) Bellville 7530

QUESTIONNAIRE SURVEY

Aims and Scope of this Survey

The aim of this survey is to obtain information from South African construction practitioners in the Cape Peninsula area in the Western Cape Province about the causes and effects of rework in construction projects so that effective prevention strategies can be developed. It is a research study undertaken by an M-tech student towards fulfilling a Master's Degree within the Built Environment Department situated at the Cape Peninsula University of Technology.

To complete the Survey

For the purposes of the survey, rework is defined as "*the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time*". Specifically, you should relate the answers that you provide to a **recently completed project** that you have been involved with. It is very important that each question is read carefully and that all questions are answered. The survey should take about 20 minutes to complete.

Construction Professionals Approached

The survey has been distributed to randomly selected construction practitioners. You are assured that the information obtained from this survey will be kept strictly confidential and will be only used for research purposes. Data will not be made available to any third party or used in any published material, except as a component in aggregated statistics.

To Return the Survey

Please complete the survey and return to:

Eric Kwame Simpeh

Cape Peninsula University of Technology

Telephone: 021 953-8621, Fax: 021 959-6656

Email: simpehe@cput.ac.za

Mobile: +27 837409941

Thank you for your cooperation and assistance.

Mark your answers by ticking the response as shown:

Example ☐√ ☐2 ☐3 ☐4 ☐5

Please answer every question.

SECTION A: PROFILE OF RESPONDENT

1. Which of the following best describes your company?

Architect ☐ Consulting Engineering ☐ Project Management ☐

Contractor ☐ Quantity surveying ☐

Other (please specify)………………………………………………………………

2. How long have you worked in the construction industry?
   ……………………………………………

3. What is your current position in your organization?
   …………………………………………………..

4. How long have you been in your present position?
   …………………………………………………..

SECTION B: PROJECT CHARACTERISTICS

5. What was the project type?

New Build ☐ Refurbishment/Renovation ☐

Other (please specify)……………………………………………………………………………

6. What was the facility type that best describes the project?

Administrative ☐	Banks ☐	Educational ☐
Entertainment ☐	Hospitals/Health ☐	Commercial ☐
Hotel/Motel/Resort ☐	Industrial ☐	Residential ☐

Other (please specify)……………………………………………………………………………

7. How much was the original tender sum?

R

8. How much was the final contract sum?

R

9. What was the project's original construction period?

10. What was the project's actual construction period?

11. What type of procurement method was used for the project?

Traditional lump sum ☐	Novation ☐
Design and manage ☐	Traditional with provisional quantities ☐
Design and build ☐	Management contracting ☐
Traditional cost plus ☐	Turnkey ☐
Construction management ☐	

Other (please specify) …………………………………………………………………………

12. What was the project's gross floor area (m^2)?

…………………………………………………

13. How many floors did the project have?

....

SECTION C: ORGANISATIONAL MANAGEMENT PRACTICES

14. Please indicate the extent to which each of the following quality practices are implemented in your organisation:

Quality Practices	**Not at all**		**To some extent**		**To a very large extent**
Measurement of quality costs (e.g. prevention and appraisal costs)	1	2	3	4	5
International Standards Organisation (e.g. ISO 9000)	1	2	3	4	5
Quality function deployment	1	2	3	4	5
Total quality management	1	2	3	4	5
Improvement to teams/work teams	1	2	3	4	5
Other (please specify) ………………………………………………………………	1	2	3	4	5

15. Please indicate the extent to which each of the following learning mechanisms are implemented in your organisation:

Learning	**Not at all**		**To some extent**		**To a very large extent**
Training programmes for staff	1	2	3	4	5
Self-learning of individuals (e.g. tradesmen on site)	1	2	3	4	5
Research and development	1	2	3	4	5
Internal benchmarking	1	2	3	4	5
Project reviews	1	2	3	4	5
Internal seminars on new developments	1	2	3	4	5
Other (please specify) ………………………………………………………………	1	2	3	4	5

SECTION D: CAUSES OF REWORK

16. The following are examples of client-related factors which might be the cause of rework. Indicate the extent to which you agree with the following statements:

Client-related factors	Strongly disagree		Neither agree nor disagree		Strongly agree
Lack of experience and knowledge of the design process	1	2	3	4	5
Lack of experience and knowledge of the construction process	1	2	3	4	5
Lack of funding allocated for site investigations	1	2	3	4	5
Lack of client involvement in the project	1	2	3	4	5
Insufficient time and money spent on the briefing process	1	2	3	4	5
Poor communication with design consultants (architect/engineers)	1	2	3	4	5
Payment of low fees for preparing contract documentation	1	2	3	4	5
Other (please specify) …………………………………………………………	1	2	3	4	5

17. The following are examples of design-related factors which might be the cause of rework. Indicate the extent to which you agree with the following statements:

Design-related factors	Strongly disagree		Neither agree nor disagree		Strongly agree
Changes made at the request of the client	1	2	3	4	5
Changes made by the contractor during construction	1	2	3	4	5
Changes initiated by the municipality/regulatory bodies	1	2	3	4	5
Errors made in the contract documentation	1	2	3	4	5
Omissions of items from the contract documentation	1	2	3	4	5
Ineffective use of quality management practices	1	2	3	4	5

Ineffective use of information technologies (e.g. CADD)	1	2	3	4	5
Poor coordination of design	1	2	3	4	5
Time boxing (fixed time allocated to task, irrespective of whether the documentation is complete or not)	1	2	3	4	5
Poor planning of workload	1	2	3	4	5
Insufficient skill levels to complete the required task	1	2	3	4	5
Insufficient time to prepare contract documentation	1	2	3	4	5
Incomplete design at the time of tender	1	2	3	4	5
Inadequate client brief to prepare detailed contract documentation	1	2	3	4	5
Other (please specify) ………………………………………………………………	1	2	3	4	5

18. The following are examples of site management-related factors which might be the cause of rework. Indicate the extent to which you agree with the following statements:

Site Management	**Strongly disagree**		**Neither agree nor disagree**		**Strongly agree**
Ineffective use of quality management practices	1	2	3	4	5
Lack of training and experience	1	2	3	4	5
Setting-out errors	1	2	3	4	5
Constructability problems	1	2	3	4	5
Poor planning of resources	1	2	3	4	5
Poor coordination of resources (e.g. Subcontractors)	1	2	3	4	5
Failure to provide protection to constructed works	1	2	3	4	5
Lack of safety	1	2	3	4	5
Excessive overtime	1	2	3	4	5

19. The following are subcontractors-related factors which might be the cause of rework. Indicate the extent to which you agree with the following statements:

Subcontractor	**Strongly disagree**		**Neither agree nor disagree**		**Strongly agree**
Unclear instruction to workers	1	2	3	4	5
Non-compliance with specification	1	2	3	4	5
Shortage of skilled supervisors	1	2	3	4	5
Shortage of skilled labour	1	2	3	4	5
Low labour skill level	1	2	3	4	5
Inadequate Supervisor/Foreman/Tradesmen ratios	1	2	3	4	5
Defective workmanship	1	2	3	4	5
Damage to other trades work due to carelessness	1	2	3	4	5

SECTION E: IMPACT OF REWORK

20. Please indicate the extent to which rework affected the performance of the project that you have selected for each of the following factors:

Project performance	Not at all		To some extent		To a very large extent
Cost overrun	1	2	3	4	5
Time overrun	1	2	3	4	5
Contractual claims	1	2	3	4	5
End-user/client dissatisfaction	1	2	3	4	5
Contractor's dissatisfaction	1	2	3	4	5
Design team's dissatisfaction	1	2	3	4	5
Quality degradation	1	2	3	4	5
Disputes between parties to the contract	1	2	3	4	5

21. Please indicate the extent to which rework affected your organisation in relation to each of the following factors:

Organisation	Not at all		To some extent		To a very large extent
Absenteeism of workers	1	2	3	4	5
Inter-organisational conflict	1	2	3	4	5
Fatigue	1	2	3	4	5
Poor morale of workers	1	2	3	4	5
De-motivation of workers	1	2	3	4	5
Loss of future work	1	2	3	4	5
Reduced profit	1	2	3	4	5
Other (please specify) ……………………………………………………………	1	2	3	4	5

SECTION F: MEASUREMENT OF REWORK COST

22. From your personal experience, how frequent did you record the incidence of rework for the project you have selected?

Never ☐ Sometimes ☐ Always ☐

23. With reference to the project you selected, to what extent do you agree with the following statements where,

Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, and Strongly agree = 5

Statement	Strongly disagree		Neither agree nor disagree		Strongly agree
The system of recording rework occurrences was efficient.	1	2	3	4	5
The system of calculating direct cost of rework was efficient (e.g. additional time, material and labour for covering rework occurrences).	1	2	3	4	5
The system of calculating indirect cost of rework was efficient (e.g. loss of schedule and productivity, litigation and claims, and low operational efficiency).	1	2	3	4	5
The adverse impact of the cost of rework on profit has not been clearly reported.	1	2	3	4	5

24. To what extent were rework costs attributable to each of the following design-related sources for the project you have selected?

Design-related sources	**Not at all**		**To some extent**		**To a very large extent**
Changes made at the request of the contractor during construction	1	2	3	4	5
Changes made at the request of the client	1	2	3	4	5
Changes initiated by an end-user/municipality	1	2	3	4	5
Revisions, modifications and improvements of the design initiated by the contractor or subcontractor	1	2	3	4	5
Errors made in the contract documentation	1	2	3	4	5
Omission of item(s) from the contract documentation	1	2	3	4	5
Other (please specify) ………………………………………………………………	1	2	3	4	5

25. To what extent were rework costs attributable to each of the following construction-related sources for the project that you have selected?

Construction-related sources	**Not at all**		**To some extent**		**To a very large extent**
Changes in the method of construction to improve constructability	1	2	3	4	5
Changes in construction methods due to site conditions	1	2	3	4	5
Changes initiated by the client or an occupier after some work had been undertaken on site	1	2	3	4	5
Changes initiated by the client or an occupier when a product or process had been completed	1	2	3	4	5
Changes initiated by a contractor to improve quality	1	2	3	4	5
Errors due to inappropriate construction methods	1	2	3	4	5
Damages caused by a subcontractor	1	2	3	4	5
Omission of some activity or task	1	2	3	4	5

26. Please indicate which areas of cost increased as a result of rework for the project that you have selected:

Cost-sources	Not at all		To some extent		To a very large extent
Preliminaries (e.g. scaffolding, carnage)	1	2	3	4	5
Fees for design consultants	1	2	3	4	5
Acceleration costs	1	2	3	4	5
Overtime costs	1	2	3	4	5
Supervision	1	2	3	4	5
Disruption costs	1	2	3	4	5
Other (please specify) ……………………………………………………………………	1	2	3	4	5

27. Please provide an estimate for the following rework costs for the project that you have selected as a percentage of the project's original contract value (%)

Direct cost ☐ Indirect cost ☐

SECTION G: REWORK CONTAINMENT STRATEGIES

28. Please indicate which of the following design management strategies were implemented in the project you have identified. Also indicate how effective the strategy was for reducing the incidence of rework:

Design management	**Tick**	**Highly ineffective**		**Quite effective**		**Highly effective**
Value management	☐	1	2	3	4	5
Design for construction (e.g. standardised components)	☐	1	2	3	4	5
Computer visualisation techniques	☐	1	2	3	4	5
Involvement of subcontractor/suppliers during design	☐	1	2	3	4	5
Constructability analysis	☐	1	2	3	4	5
Design scope freezing	☐	1	2	3	4	5
Team building	☐	1	2	3	4	5
Other (please specify) …………………………………………………………	☐	1	2	3	4	5

29. Please indicate which of the following site management strategies were implemented in the project you have identified. Also indicate how effective the strategy was for reducing the incidence of rework:

Site management	**Tick**	**Highly ineffective**		**Quite effective**		**Highly effective**
Involvement of subcontractors during construction	☐	1	2	3	4	5
Site quality management system	☐	1	2	3	4	5
Quality control	☐	1	2	3	4	5
Quality audits	☐	1	2	3	4	5
Value engineering	☐	1	2	3	4	5
Other (please specify) …………………………………………………………	☐	1	2	3	4	5

30. Please provide details of any issues that you feel were not addressed.

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APPENDIX C – PUBLICATIONS AND CONFERENCE PAPERS MADE DURING THE COURSE OF STUDY

Simpeh, E.K., Ndihokubwayo, R. & Love, P.E.D. (2011) Field diagnosis of causes and effects of rework in higher education residential facilities, *Journal of Construction,* ISSN 1994-7402, Vol. 4 Issue 1 pp 17-24

ABSTRACT

Purpose: The aim of this paper is to examine the causes and effects of rework occurring in construction projects so that effective containment and reduction strategies can be developed.

Methodology: Case studies were conducted on purposive selected construction projects based in Cape Town, South Africa, to establish the causes and effect of rework. Specifically, qualitative data was collected by means of observation of physical works, semi-structured interviews with relevant parties directly involved in site operation, including the contractor’s management team, consultants and subcontractors. Also, site instruction record documents were analysed.

Findings: It was revealed that changes initiated by the client, changes initiated by the design team due to errors and omissions, and poor coordination and integration among the design team were the major contributing factors to rework. Moreover, constructability problems, lack of skills, and emphasis on time and cost aggravated the occurrence of rework on site. It was also established that rework has both direct and indirect consequences such as cost for redesign, cost of demolition, cost of litigation, poor morale, de-motivation and loss of market share in construction projects.

Limitations: Only two multiple storey educational facilities were analysed, and as a result, the reported findings cannot be generalised. In addition, causal histories for identified rework events tended to be grounded in the views of the contractors, and as result there is a potential for bias to exist. However, the findings reported are akin to what the normative literature has reported.

Value: The study suggests that design and construction firms must develop organisational measurement systems to track rework. It is only through determining its frequency and cost can effective strategies for rework containment and reduction be identified.

Keywords:

Causes, construction, errors, omissions, rework

Simpeh, E.K., Ndihokubwayo, R. & Love, P.E.D. (2012) Evaluating the direct and indirect costs of rework in construction, *8th International Cost Engineering Council (ICEC) World Congress*, 23 – 27 June 2012, Durban, South Africa (awaiting publication date)

ABSTRACT

Purpose of this paper:

This paper investigates the potential for compromise with quality as a consequence of direct and indirect costs associated with undertaking rework in construction project.

Design/methodology/approach:

Literature pertaining to direct and indirect cost of rework and associated waste has been reviewed. A quantitative approach was adopted and data was collected via a questionnaire survey targeting purposively selected construction professionals in the Cape Peninsula metropolitan area. Descriptive (mean) and inferential (one-way analysis) statistics were used to analyse the data.

Findings:

A total of 78 firms participated in this study. It was found that the mean of direct and indirect cost of rework were 2.93% and 2.20% of the contract value respectively. In addition, it was established that the majority of the respondents do not always have systems in place for tracking and recording the incidence of rework and its cost impact, especially the indirect costs. The study also revealed that there are significant differences between respondents' estimates for direct rework costs. Furthermore, the study revealed no significant differences between respondents' estimates for indirect rework cost.

Originality/value of paper:

To reduce these costs and thereby improve overall project performance, it is posited that design and construction organisations must improve their quality management practices by introducing a tracking mechanism for continuously quantifying the direct and indirect costs of rework, so that an understanding of their magnitude can be captured and effective containment strategies implemented.

Keywords: Rework, cost overruns, consequences, construction project

Simpeh, E.K., Ndihokubwayo, R. & Love, P.E.D. (2012) Influence of Procurement Method on the occurrence of Rework in Construction Projects,

***8th International Cost Engineering Council (ICEC) World Congress*, 23 – 27 June 2012, Durban, South Africa (awaiting publication date)**

ABSTRACT

Purpose of this paper:

The research presented in this paper aims to determine the influence of different procurement methods on rework occurrences in construction projects.

Design/methodology/approach:

Pertinent literature review with specific regard to procurement methods influencing the occurrence of rework has been provided. A questionnaire survey was presented to purposively selected construction professionals based in the Cape Peninsula metropolis. Descriptive (mean) and inferential (t-test) statistics were used to analyse the data.

Findings:

Data were obtained from 78 construction professionals. The causes of rework were analyzed and discussed. It became apparent that rework causes do not differ relative to various procurement methods.

Originality/value of paper:

It is posited that design and construction organisations need to improve the quality of operations throughout the procurement process in order to reduce the occurrence of rework and thereby improve overall project performance.

Keywords: Rework, procurement, causes, construction project

Simpeh, E.K., Ndihokubwayo, R., & Love, P.E.D. (2012) Impact of rework on construction schedule performance, *1st Applied Research Conference in Africa (ARCA)*, 29 – 31 August 2012, Elmina, Ghana (awaiting publication date)

ABSTRACT

Purpose of this paper:

This paper aims to determine and evaluate the impact of rework on construction time performance during actual construction.

Design/methodology/approach:

A total of 78 participants from both construction companies and consulting firms participated in this study. A quantitative method was adopted and data was collected via structured questionnaire survey targeting purposively selected construction companies and consulting firms in the Cape Peninsula in the Western Cape Province of South Africa. The data analysis techniques used were descriptive (mean) and inferential (one-way analysis) statistics.

Findings:

Results indicated that the four principal causes of schedule overrun as a result of rework were as follows: poor communication with design consultants (e.g. architect/engineers), changes made at the request of the client, setting out errors, and finally, non-compliance with specification during the construction stage. The findings also revealed that some projects experienced 100% time overrun.

Originality/value of paper:

It is hoped that the principal rework factors identified that triggered significant schedule overrun experienced in this survey will provide a basis for further studies into other factors that contribute to schedule overruns so that effective strategies can be developed to minimise delays in the South African construction industry.

Keywords: construction, rework, South Africa, time overruns

Simpeh E.K., Ndihokubwayo R. & Love E.D. (2012) Determinants of rework costs: a comparative analysis of new build project and renovation/refurbishments project in the South African context, *1st Applied Research Conference in Africa (ARCA)*, 29 – 31 August 2012, Elmina, Ghana (awaiting publication date)

ABSTRACT

Purpose of this paper:

The research presented in this paper quantifies the magnitude and costs of rework experienced in new build and renovation/refurbishments projects.

Design/methodology/approach:

Pertinent literature related to rework costs and its associate impact has been reviewed. A total of 78 participants from both construction companies and consulting firms participated in this study. A quantitative approach was adopted and data was collected via questionnaire survey targeting purposively selected construction professionals in the Cape Peninsula metropolis. The data was analysed using descriptive (mean) and inferential (one-way analysis) statistics.

Findings:

The findings reveal that refurbishment/renovation projects experienced higher rework cost compared to new build projects because of the degree of uncertainty and complexity associated with the building work to be undertaken. The total costs of rework as a percentage of the original contract value for new build projects and renovation/refurbishment projects was 4.89% and 6.28% respectively. Nevertheless, rework costs do not differ significantly between new build projects and renovation/refurbishment projects.

Originality/value of paper:

Creating the awareness as to the impact rework costs can have on project performance is probably the most obvious intervention and the starting point for establishing an in-depth knowledge of the root source of rework. Once understanding of the magnitude of rework costs has been acquired, effective strategies for its reduction can be designed and implemented in order to improve project cost performance.

Keywords: new build project, renovation project, rework costs, rework, South Africa

Simpeh, E.K., Ndihokubwayo, R. & Love, P.E.D. (2011) An analysis of the impact of rework on project performance: views from the field, *The Sixth Built Environment Conference*, Association of Schools of Construction of Southern Africa, 31 July - 2 August 2011, Johannesburg, South Africa

ABSTRACT

Purpose: This paper assesses the impact of rework on construction project performance. In addition, it identifies the root causes of rework during the design development process.

Methodology: Case study approaches based on purposively selected projects were used to analyse the impact of rework on project performance. Interviews were conducted with consulting engineering firms to obtain data.

Findings: The findings of this study establish that the impact of rework is not significantly different between the two projects. Changes initiated by the client and contractors, together with design-related sources such as errors and omissions in contract documentation, were found to be the primary causes of rework. Particularly in project 'A' rework was exacerbated by changes made at the request of the municipality to comply with new fire safety regulation.

Limitations: The study was conducted in Cape Town and limited to two multiple storey educational facilities, and as a result the reported findings cannot be generalised. In addition, causal histories for identified rework events tended to be grounded in the views of the design consultants which means there is a potential for bias to exist. However, the findings reported are akin to what the normative literature has reported.

Value: To reduce the impact of rework on project performance, it is suggests that construction companies and consultant firms (particularly design consultants) need an understanding of its causal structure during the design development process so that effective prevention strategies can be identified and the impact of rework reduced and perhaps even eliminated.

Key words: causes, construction, errors, omissions, rework, waste

Simpeh, E & Ndihokubwayo, R (2010) Barriers to innovation in design: perspective of designers, *The South African Council for the Quantity Surveying Profession (SACQSP) Conference*, *The P8 Summit*, ISBN 978-0-620-48105-2, 15 October 2010, East London, South Africa

ABSTRACT

Purpose: This paper aims to investigate the barriers for the implementation of innovation in housing design in order to take improvement measures.

Methodology/Scope: An extensive relevant literature review with specific regard to innovation, barriers to innovation and benefits of innovation has been provided. A questionnaire survey was done on purposively selected architectural firms involved in housing designs in Cape Town.

Findings: In total, 15 respondents participated in the survey. The findings reveal that shortage of skills and cost implications during the design phase were the major barriers to innovation in housing designs. Furthermore, regulations of associations and South African Bureau of Standards (SABS) have a huge impact on housing designs because designers are restricted to some extent including building lines, height, zoning, coverage and bulk restrictions.

Research limitations: The study was confined to housing designs and the survey was conducted to examine designers' perspectives on barrier to innovation. Perception of other stakeholders in the construction industry should be further examined.

Practical implications: The findings revealed that in order to encourage innovation in housing designs, it is imperative to educate all role-players in the housing industry. This will likely promote sustainable designs which, in a nutshell, will result in reduced construction and maintenance costs.

Key words: barriers, housing, innovation

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