Project Management: An Analysis of Causes and Effects of Rework on Construction Project

إدارةالمشروعات: تحليل أسباب وآثارإعادةالعمل على مشروع أنشاءات

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Abstract

The significance of construction projects to any nation or society cannot be over emphasized. However, various challenges affect the successful completion of construction projects. In this research, the main causes of rework and the effects on project performance have been studied.

This research was carried out on an ongoing pipeline construction project situated in Libya and data was collected from three main areas: 50 samples of non-conformance report (NCR); financial information; interviews with the key staff working directly on the pipeline project. After the identification of the project categories, the analysis of the interviews was conducted using qualitative coding as the method for identifying the root causes of the rework on the pipeline project. The financial information of the project that was obtained from the financial head was used to substantiate the outcomes of rework impact on the pipeline project based on the overall project performance.

The research findings indicated that the main causes of the rework on the project were closely related to: people; process; technology; communication; materials; machines and equipment. Moreover, it was found that the inadequate supervision; erroneous workmanship; lack of job experience; poor training-culture of the organization; machines delivered with defects; complication of the machines; language barriers and poor work procedures among other minor faults are the root causes of the rework.

These causes triggered consequential effects on the project performance such as: fatigue and stress among others. The average rework calculated for the project categories identified in the pipeline project revealed that there was 4.7% increase in the total cost of the project. Recommendations are also made so that the cost of rework may be reduced considerably at the end of the project by: ensuring effective communication among the staff; improving the training of the staff; increasing the amount of supervision; usage of right materials and ensuring the usability and functionalities of the machinery and equipment.

Keywords: Rework, Rework Index, Project Performance

ملخص البحث:

تعتبر مشاريع الإنشاءات ذات أهمية بالغة في أي مجتمع أو مؤسسة ومع ذلك هناك العديد من التحديات التي تؤثر على إنهاء هذه المشاريع بنجاح. في هذا البحث تمت دراسة الأسباب الرئيسية لإعادة تنفيذ العمل (Rework) وآثارها على أداء المشروع.

أجرى هذا البحث على مشروع تحت التنفيذ خاص بإنشاء خط أنابيب مياه بدولة ليبيا. تم تجميع البيانات الخاصة بالبحث من ثلاثة محاور رئيسية هي: 50 عينة من تقارير عدم المطابقة لبعض أعمال المشروع (NCR)، المعلومات المالية، مقابلات شخصية مع بعض العاملين في المشروع. بعد تحديد المراحل الأساسية في المشروع تم تحليل بيانات المقابلات الشخصية باستخدام الترميز النوعي كاسلوب لتحديد الأسباب الجذرية التي أدت إلى إعادة تنفيذ العمل (Rework) بهذا المشروع.

كذلك تم استخدام المعلومات المالية التي تم الحصول عليها من الإدارة المالية بالمشروع لدراسة تأثير إعادة تنفيذ الأعمال (Rework) على الأداء العام للمشروع.

من خلال نتائج البحث اتضح أن الأسباب الرئيسية لإعادة التنفيذ العمل (Rework)مرتبطة ارتباطاً وثيقاً: الأفراد، خطوات العمل التنفيذية، التكنولوجيا، المواد، الآلات والمعدات. إلى جانب ذلك، فقد تبين أن عدم كفاية الإشراف، أخطاء الأفراد، نقص الخبرة في الوظائف، عدم وجود برنامج تدريبي، تسليم المشروع الآلات بها عيوب، الحواجز اللغوية، ضعف في خطوات العمل التنفيذية هذا إلى جانب بعض الأخطاء البسيطة الأخرى وجميعها تعتبر من الأسباب الجذرية لإعادة تنفيذ الأعمال. وكذلك وتتمثل تتابعات تأثير هذه الأسباب على العاملين في الآتي: التعب والإجهاد وضغط العمل.

ومن خلال احتساب متوسط قيمة الأعمال التي تم إعادة تنفيذها يتضح أن نسبتها 4.7% وهذه النسبة تعتبر زيادة في اجمالي تكلفة المشروع. تمت التوصية بأنه يمكن أن يتم تخفيض تكلفة إعادة تنفيذ الأعمال (Rework) في نهاية المشروع وذلك في التركيز على الآتي: تفعيل التواصل الجديد بين العاملين بالمشروع، تحسين برنامج التدريبي للعاملين، تحسين الاشراف، استخدام المواد المناسبة، ضمان سهولة استخدام الآلات والمعدات.

الكلمات الرئيسة: إعادة تنفيذ الأعمال (Rework)، مؤشر إعادة تنفيذ العمل، إدارة المشروع

Acknowledgement

The completion of this dissertation would not have been possible without the support of the staff of the construction company, particularly the financial head and other relevant departments of the company. Their immense help has enabled me to collect the relevant data needed to accomplish this dissertation. It is with great delight that I wish to thank my supervisor, Dr Arun Bajracharya, for his assistance throughout the duration of the dissertation. I wish also to acknowledge Professor Muhammad Dulaimi and Professor Paul Gardiner for making the project management programme such a worthwhile one. Finally, I also thank all BUiD staff for their support and encouragement extended.

Dedication

I dedicate this dissertation to my wife and children for their patience, understanding and support in making this dissertation an accomplishment. My regards also go to the entire staff working in my company for easing my task especially, when the going got tough.

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Chapter 1.0: Introduction

Chapter 1.0 Introduction

1.1 Background

Over the decades construction work across the globe has been a means for countries upgrading their national economies. In order to sustain this growth, different factors (that affect the operations and productivity in construction projects) should be considered. It has now become a known fact that construction industries often experience rework in construction projects, which is definitely not desirable and has a negative impact on project cost and its performance. A research conducted by the Construction Industry Institute (CII) shows the direct cost escalation as a result of rework on an average of 5% of the total construction cost (CII 2005). Prior to this, several researchers investigated the causes of rework and its impact on construction cost (O'Conner and Tucker 1986; CII 1989; Burati et al. 1992; Love et al. 1999a, b; Love 2002b; Fayek et al. 2003; Love and Edwards 2004). All these findings point to the fact that rework creates an adverse impact on construction cost. What then is rework? What causes rework to be necessary in construction projects, and what are the resultant impacts on total construction cost and performance? These are the key research questions considered in this research work.

Rework is referred to as the process of repeating an activity that has already been completed or activity that was incorrectly implemented in the first instance (Love, 2002). Most construction projects have got an assortment of causes that leads to rework, this include; omissions, alteration, failures, proper communication, and inadequate coordination and collaboration between stakeholders. Invariably, the impact of rework has badly impacted on the productivity, performance, and finance of a project.

According to Wasfy (2010) defines two categories of rework causes, direct and indirect, a study were composed in the light of this model. Some of the direct causes that lead to rework has been attributed to poor supervision, incompetent supervision, poor workmanship, defective material, and error in designs. In general, a greater part of indirect causes usually create a situation that leads to the rework. These indirect rework were majorly attributed to issues like poor subcontractor selection, significant collaboration among worker, and improper work sequence.

There is a general consensus by most researchers as observed in the literature that the rework although prevalent to some extent in all projects, is not intrinsic and can be avoided. In some research findings, an overall estimation of 2.40% and 3.15% of the project cost has been attributed to industrial and residential buildings respectively due to rework (Love and Li 2000). This research will focus on rework in one construction project in Libya in order to investigate the possible causes (direct and indirect) of the rework impact on cost. It also suggests some possible solutions to reduce rework to a minimum.

1.2 Project Description

The project was launched by a company based in Libya (to maintain anonymity it will be called DACAL). The project entails a long-running water supply system across a distance cutting across towns in Libya. The project started in November 2010 and duration for completion was 48 months. The main contractor was a multi-national company based in Turkey, and it was expected that by the end of the year 2014 a 383km long pipeline would have been completed in conformity with the contract signed. A brief summary of the project is given in Table 1 below.

Table 1: Shows the project profile

	Water Supply System Project
Project Name	DACAL (Construction of a water supply system)
Contract Type	Design and Build
Project Value	980,000,000 USD
Project Duration	48 Months
Project Stage	Three
Progress Ratio	76%
Project Starting Date	22/10/2010
Report Analysis Date	15/9/2013

1.3 Problem Definition

Poor project performances which were associated with project delay and cost overrun were some of the outcomes of the infrastructure designs. These outcomes precipitated the need to investigate the impact of rework which served as the underlying cause of the problem. Accordingly, the causes of rework and its impacts on total construction project cost of this nature need to be studied, while the possible findings could be suggestions to prevent or reduce rework in this project and similar construction projects.

Earlier research identified three major rework issues; initial contractor design error, contractor construction error, and insufficient on-site supervision (Akin, 1986; Miller, 1993; Rounce, 1998; Love and Li, 2000) and these factors may be synonymous to the project at hand. These factors usually impact greatly to the project cost performance as a result of delay born out of unapproved project activities. Due to the delays encountered in the project, rework is necessary to put the project back on track, as well as to meet the client expectations. This was the case in the Libya water pipeline project where records observed shows that contractors only focused on getting the work done without given enough time to investigate the main causes of rework which may have helped to eliminate such rework from reoccurring in the project.

1.4 Aim of research

The aim of this research is to investigate, analyze and discuss the causes and effect of rework in a construction project.

1.5 Objectives

The objectives of the study are as follows:

(1) To investigate the prevalence of rework in the pipeline projects
(2) To determine the major underlying causes of rework
(3) To determine the impact of rework on overall project cost

(4) To suggest viable recommendations to reduce the occurrence of rework and its adverse impact

1.6 Research Hypotheses

In most construction work, three key aspects have been found to be inherent in the success of a project; these are the people (human involvement), the processes, and the technology. As will be seen in the literature review of this study, the people involved in the project can be the following; clients, contractors, sub-contractors, consultants and the vendors. Similarly, the process of execution of a project would involve the documentation, communication channels, designs, transportation means, organization procedures, and adopted project management practices. The technology entails the sort of equipment to be used in the execution of the project, and software needed to accomplish the construction work. Thus, the research study is interested in ways in which these three aspects could be contributing factors to rework that adversely impact on the overall project cost and its performance.

The hypotheses for the research study are stated below:

HI: There is a significant relationship between the people and the rework in construction projects

H2: There is a significant relationship between the process and the rework in construction projects

H3: There is a significant relationship between the technology employed and the rework in construction project

H4: The impact of rework has a great influence on the performance of the project

H5: The impact of rework has a great influence on the total project cost

1.7 Research Rationale

The research will examine the causes of rework on a large scale water supply pipeline in Libya. The research is of particular interest knowing well that causes and impact of rework have been identified in the construction project but there are only a few researchers that have conducted research in identifying the causes of rework on a huge pipeline project of this nature and examining the impact of such rework on the total construction cost. In carrying out this research, it might be possible to discover some possible causes of rework since large pipeline projects are affected by the global economic conditions. Thus, some causes of rework may be engendered from the following factors: clients change order; regulatory bodies; weather; unforeseen risk and public bodies. The outcomes of the research findings will shed more light on the issue.

1.8 Scope of research study

Although the impact of rework cut across time, quality of work, and cost, the study is confined to identifying the causes of rework, implication of the rework on project performance and the impact on the total cost of construction project. It is also important to note that the research is basically assessing those factors from a huge pipeline water project in Libya, and as such, some other causes of rework pertaining to building infrastructure may not be included in the result findings. A factor worthy of note is that the financial details used for the research study entails only the planned cost and the actual cost of the project after the activities of the non-conformance report (NCR) has been duly corrected to satisfy the contract requirements. In other words, only rework costs as per the NCR are considered and not any incidental costs that may have occurred to increase the planned cost.

1.9 Research Structure

The research study intends to examine the causes of rework in a large pipeline water system project and determine its extent of impact to the overall total construction project cost. Having been identified by researchers that many of the causes of rework are due to human error ranging from errors or omissions, a better method of investigating these causes could be a qualitative approach methodology. Accordingly, the study begins with a review of the literature on the various definition of rework; it then goes on to identify the factors and classifications of rework. Thereafter, a collection of field reports were gathered which serves as the data and examining the root cause(s) of the problem by a semi-structured interview with concerned staff. Afterwards, a theoretical coding of the interviews (which served as the research method for the research study) was adopted. Finally, the result of the investigation shows the causes and the impact of the rework on the total construction cost on the project. In total, the structure of the report comprises six chapters which are presented in a logical sequence as the research progresses.

Chapter 1: Introduction - The first chapter begins with the introduction of the research topic and its background. It further includes the definition of the problem statement, the aim of the research study and those objectives which are expected to be achieved in the study, including the research questions that precipitated the research study.

Chapter 2: Literature review – The second chapter deals with the literature review of earlier research study on rework covering the causes of rework in construction projects and its impact on the total project cost and project performance.

Chapter 3: Research Methodology – In the third chapter, the methodology used to conduct the research study is explained. This includes the collection of the data; the interviews that are conducted which precipitated the research findings that are used to address the objectives of the study.

Chapter 4: Research Discussion and Analysis – The fourth chapter shows the findings of the research study and also the data collected during the research.

Chapter 5: Result of the Research – In the fifth chapter, the result of the research study was discussed in such a way that the research problems can be seen to have been addressed by the study by an appropriate comparison of the estimated start-up value with the result values including identification of rework in the study.

Chapter 6: Conclusion and Recommendation – The sixth chapter covers the inferences of the research study and suggestions to reduce rework in pipeline construction projects resulting in the reduction on the total construction project cost due to rework.

Chapter 2.0: Literature Review

Chapter 2.0 Literature Review

In construction and engineering management, there exist a number of factors that contribute to projects not being completed on time to the required quality and within budget; one of these causes is rework (Gyles, 1992; Walker, 1994; Love, 2002a). This has brought about a significant reason to look carefully into the issue of rework in construction projects. What then is rework?

2. 1 Definition of Rework

Various suggestions have been put forth as to the definition of rework; among these definitions we are offered: rework is activities in the field which have been completed but were required to be repeated or undertaken again as a result of some impeding correction that was necessary to be carried out during the project regardless of source, or effecting a change order not due to change of scope by the owner (Fayek, et al. 2003). It was analyzed by researchers that only delay in field operations results in rework. However, there were other contending definitions suggested by other researchers, where rework was revealed to be a significant factor that contributes to schedule delay in project and cost overruns (Chan and Kumaraswamy, 1997; Thomas and Neapolitan, 1994). Further studies reveal rework is "quality deviation" (Burati et al. 1992, p36); "non-conformance" (Abdul-Rahman, 1995, p25); "defects" (Josephson & Hammarlund 1999, p77); and "quality failures" (Barber et al. 2000, p482). Thus, based on the various interpretations within construction management literature, Love (2002) identifies two main definitions of rework as; "the process by which an item is made to conform to the original requirement by completion or correction" (Ashford, 1992) and "doing something at least one extra time due to non-conformance to requirements" (Construction Industry Development Agency, 1995). Love et al. (2000) explains that rework can be defined as "the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time". Love et al. (1997) carried out a study that looks at what could have brought about rework. In this study, it was identified that certain main factors brought about rework- people, design, and constructors.

2.2 Origin of Rework

According to Davis et al. (1989), certain factors are the cause of rework in construction projects, and these have been classified into five origins of rework. A summary of their definitions are presented in Table 2.

i. Client Related
ii. Design Related
iii. Constructor Related
iv. Vendor Related, and
v. Transporter Related

2.2.1 Client Related

Palaneeswaran (2006) identified there are some issues attributed to clients that engender rework in construction projects. These client factors relate to poor experience and knowledge of design, and processes involved in the construction work, inadequate funding allocated for site investigations, early involvement in the construction process, inadequate communication with design consultants and proper administering of contract documents. Each of these areas has been identified as a cause of deviations that result in change, error, or omission (Dalty and Crawhaw, 1973). A proposed recommendation found in the literature was that clients and the executor of projects should embrace a mutual communicative approach (Walker 1994).

2.2.2 Design Related

When there is an inadequacy in documentation, there is need for the design team to ensure contractors are provided with the assessment design status and the potential for change as signified by construction industry institutes (CII 1990). Failure to provide this fact also brings about rework when contractors act otherwise due to communication problems (Josephson and Hammarlund 1999). A study conducted by Love and Li (2000) reveals that a major cause of rework lies in the coordination and proper integration of design team members restricting the flow of information. Equally, technological gaps between the engineer and architects have resulted in drawings and dimensional errors that invariably result in rework at the point when such errors are detected (Love et al. 2012).

2.2.3 Constructor Related

The competency of the constructor (main contractor) is necessary to ensure proper coordination of all other subordinates that will be working alongside on the project (Chan 1998; Walker 1994). This would ensure the effectiveness of managing the site teams and subcontractors. According to a business roundtable meeting held in 1982, it was concluded that the inability of the contractor's supervisor to plan effectively, schedule tasks, and communicate efficiently, results in mistakes that lead to reworking of completed activities. In a further study conducted by Cusack (1992), he explains that the non-implementation of quality system (i.e. improper selection of sub-contractors, poor workmanship, inadequate supervision) to check mate processes brings about 10% increases in the amount of rework to be done.

2.2.4 Vendor Related

The process by those handling the procurement process needs to be optimized so that the occurrence of rework is reduced in such a process (Love et al. 1999a). As it has been recognized that the success of a project is dependent upon the effectiveness of the main contractor's (and their subcontractors and suppliers), thus construction progress depends on this fact (Chan, 1998: Faniran et al., 1999; Walker, 1994). It has been further emphasized that other concerning areas upon which rework comes to play by the vendors lies in poor use or choice of materials (Josephson et al. 2002).

2.2.5 Transporter Related

The changes occurring with regards to transportation have been attributed to error resulting from accidents, lack of knowledge to ensure safety, and changes resulting from error that lead to quality deviations, and have to be amended.

Table 2: Definitions of Origin of Rework

Origin of Rework	Definitions and examples
Client Related	Changes resulting from poor project definition, poor communication, poor knowledge of design, inadequate funds.
Design Related	Changes that occur as a result of error or omission in the project design or requirement.
Constructor Related	Error/Omissions made by constructor due to change in construction methods, sequence of activities, procedure or job functions, inadequate supervision. Also, changes could occur as a result of change in constructor
Vendor Related	Changes resulting from items necessary for execution were erroneously omitted by vendor. Also, changes can occur as a result of change in vendor
Transportation Related	Changes occurring due to mistake during transport, accidents or transportation error

2.3 Multiple Causes of Rework

In an assessment conducted by Love et al. (1997), the report states the main causes of rework to be people, design, and construction. It was explained that each group has its representation arms by which it brings about rework in construction projects; this has been depicted in Figure 1.

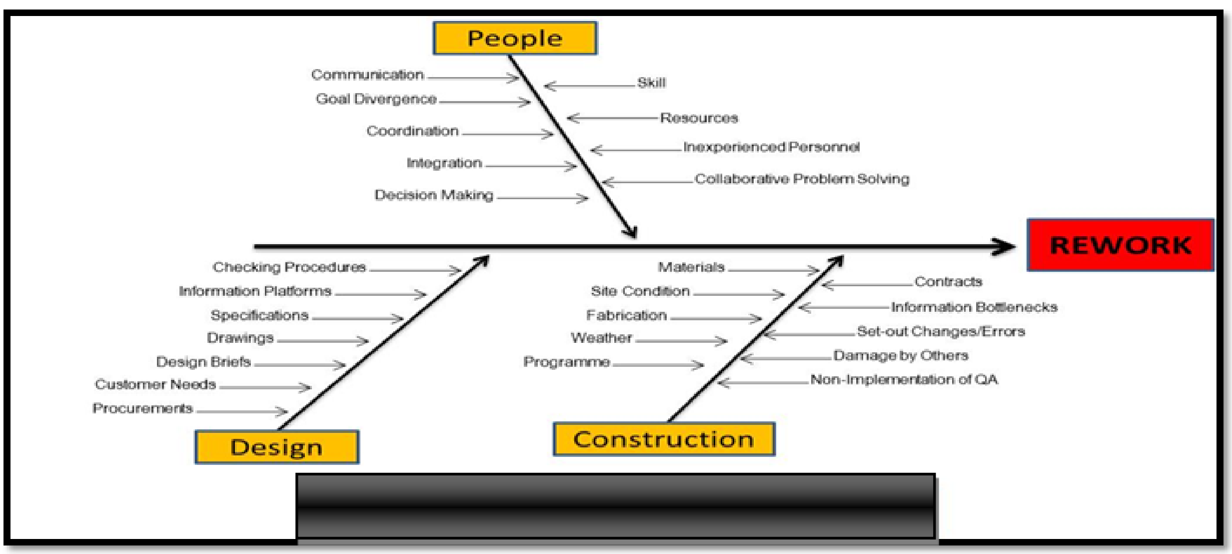

Figure 1: Generic cause and effect rework diagram (Love et al., 1997)

Similarly, Evans and Lindsay (1996), and Mandal et al. (1998) express that a system of construction project work can be classified into three sub systems as follows: technical and operational, human resources and quality management. Upon this, Love et al. (1999a) developed a model that shows the factors influencing the causes of rework illustrated in Figure 2. As noted in their study, technical/operational encompasses the operating environment, technological advancement, level of technical know-how and the adopted methodology. All these are said to be intrinsic to quality that overall forms the process, strategic formation and the ways of ensuring that customer satisfaction is achieved. In the case of human resources, the attributes attached to it are the methods of communicating information, skill availability, manpower and employee's readiness status. Also, these enumerated factors influence the skill acquisition of the employee, the training level, building up motivation for employee, and enhances the right decision making in the construction arena and their organization make up as a whole.

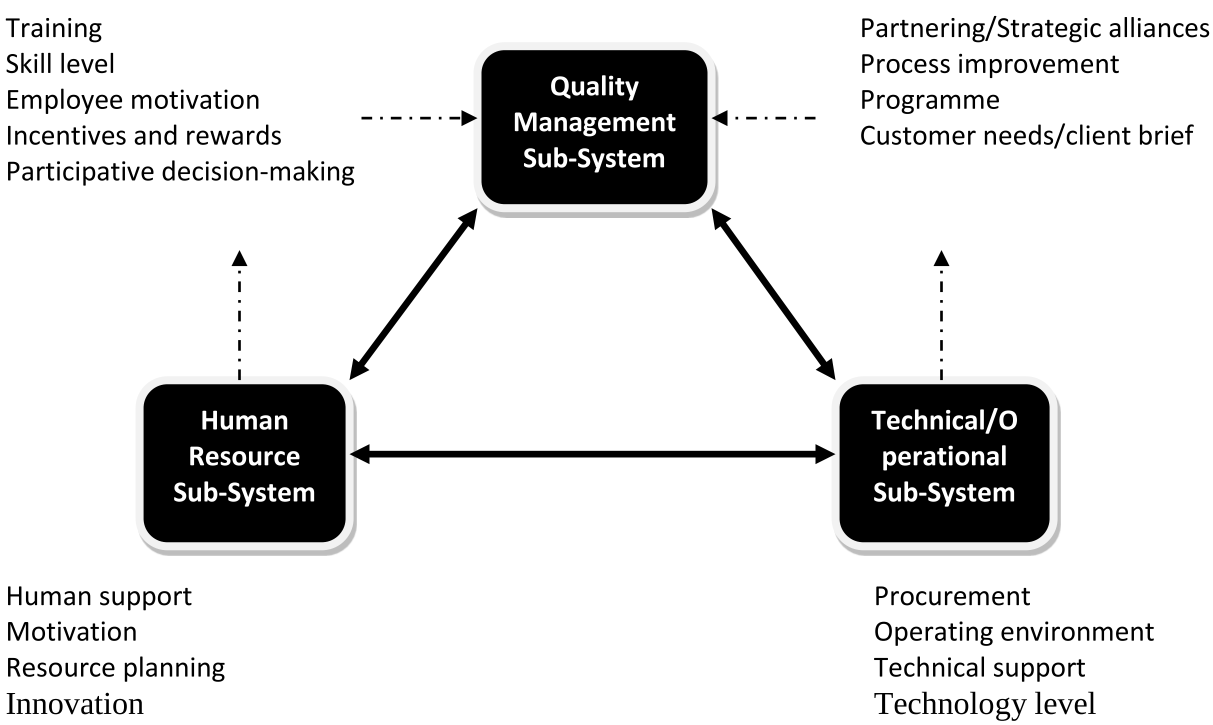

Figure 2: Interactions among the three sub-systems of a project (Love et al., 1999a)

In an account to understand what influences rework directly and indirectly, Wasfy (2010) defines two categories of rework into direct and indirect causes of rework. The direct factors are said to be the factors that affect the rework directly on field operations, and these have been identified as lack of proper supervision of construction projects, incompetent supervision, poor workmanship, defective material, and design errors. On the other hand, indirect rework causes have been classified as situations that will lead to rework, which include: improper subcontractor selection, poor work protection, lack of collaboration, and improper work sequencing. A diagrammatical representation of the two forms of rework is illustrated in the Figure 3 below:

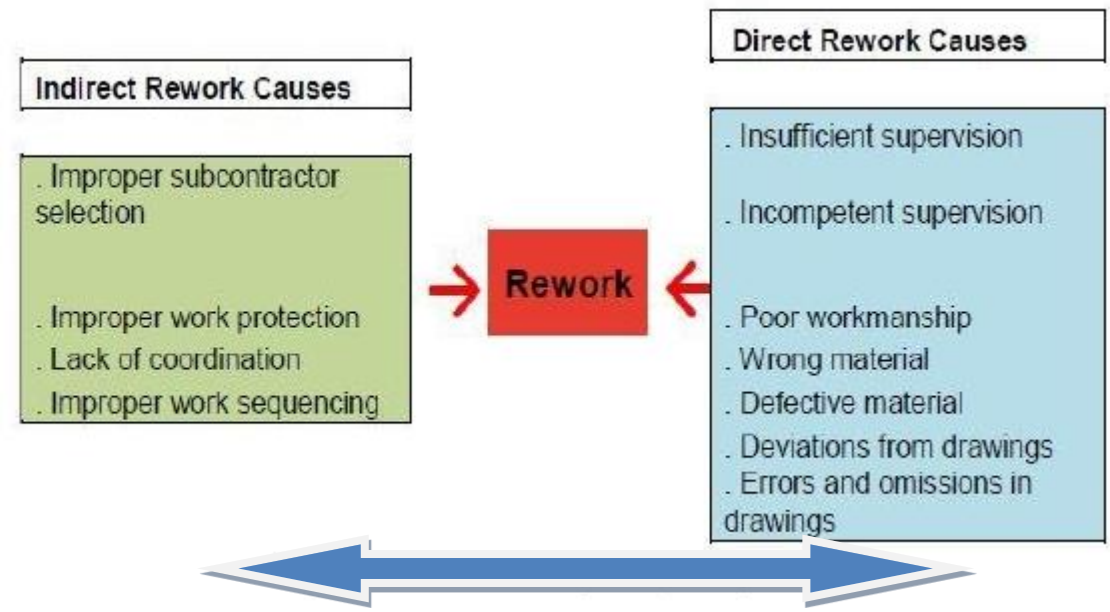

Figure 3: Rework Categories (Wasfy, 2010)

In other categories of rework, client-initiated changes, non-variations, and defects have been identified (Love and Li 2000). Thus, it was concluded that various causes of rework are interrelated due to the complexity of construction operations.

2.4 Classification of Rework

After the identification of the causes of rework in construction projects, several researchers have proceeded on classifying these causes. According to Burati et al. (1992), their results reveal the classification of rework in an undertaken study of construction projects to be categorized as design and construction as shown in the Table 3. The categories included the types of the rework, the factors causing the rework and their descriptions. In explaining the types, Love et al. (1998) stress that rework in construction projects are aggravated by error made in the design process and only manifest during the procurement stage. The longer the error goes unnoticed, the greater the impact will be on the cost and schedule of the project (Love et al., 2009).

The manifestations of error in such instances in most cases become evident during the incorporation stage (Busby and Hughes 2004), thereby prolonging the extent of rework to be done on such a project. Similarly, omission contributes greatly to rework in a project, and this may be as a result of the work practice of the organization not incorporating sufficient project management procedure during the execution of the project. A study conducted by Love et al. (2009) investigated the impact of omission in construction and resource engineering projects. It was revealed that a major factor contributing to omission is the design fee when discussing the design related rework.

Table 3: Rework Classification System (Burati et al. 1992)

Category	Type	Tertiary	Description used
Design	Change	Construction	A change is made at the request of the contractor
		Client/client rep	A change made by the client/clients' representative to the design
		Occupier	Design change initiated by the occupier
		Manufacture	A change in design initiated by a supplier/manufacturer
		Improvement	Design revisions, modifications and improvements initiated by the contractor or subcontractor
		Unknown	The source of the change could not be determined, as there was not enough information available. Discussion with project manager does not reveal the cause
	Error		Errors are mistakes made in the design
	Omission		Design omission results when a necessary item or component is omitted from the design
Construction	Change	Construction	A change in the methods to construction in order to improve constructability
		Site conditions	Changes in construction methods due to site conditions
		Client/client rep.	A change made by the client/clients' representative after some work has been performed on-site.
		Occupier	Occurs when a product or process has been completed
		Manufacture	Process or product needs to be altered/rectified
		Improvement	Contractor request to improve quality
		Unknown	The source of the change cannot be determined, as there is not enough information available. Discussion with project manager did not reveal the cause
	Error		Construction errors are the result of erroneous construction methods or procedures
	Omission		Construction omissions are those activities that occur due to omission of some activities
	Damage		Damage may be caused by a subcontractor or inclement weather

When discussing the change factor as a reason causing rework in a project, Burati et al., (1992) stated that a change in any form of the project after work has been executed, alters the established project requirement which results to reworking the construction. According to CII (1990), they stress that rework in the form change impacts negativity to the project, in which reducing the productivity of the workers and the entire project performance may be treated.

On a broader view, Construction Owners Associate of Alberta (COAA, 2002) further reclassify rework causes as fishbone likely shape as shown in Figure 4, the result of a study undertaken by (Ruwanpura et al. 2003), which was used to depict a situation of cause and effect of what brings about rework in construction work. The contributing factors were classified into five different branches as follows:

- Human resource capability: It was expressed that some major contributors to rework in construction work are inadequate supervision, lack of skillful workmanship, deficiency on the part of the instructor and poor job planning.
- Leadership and Communications: Inability of the leader to enforce proper quality management in order to ensure control commitment on the part of the subordinates, poor communications and poor implementation of safety standards contribute greatly to rework.
- Engineering and Reviews: Error, omission and change characterize the problem in engineering design that is accompanied by poor document control and the alteration in scope changes.
- Construction planning and scheduling: Some of the resulting factors of construction planning and scheduling brings about construction problems, insufficient profit gain, late implementation of design and unrealistic schedule.
- Material and Equipment: Not getting materials at the right time, materials not meeting project requirement and compliance issues are the subsequent effects of poor material handling.

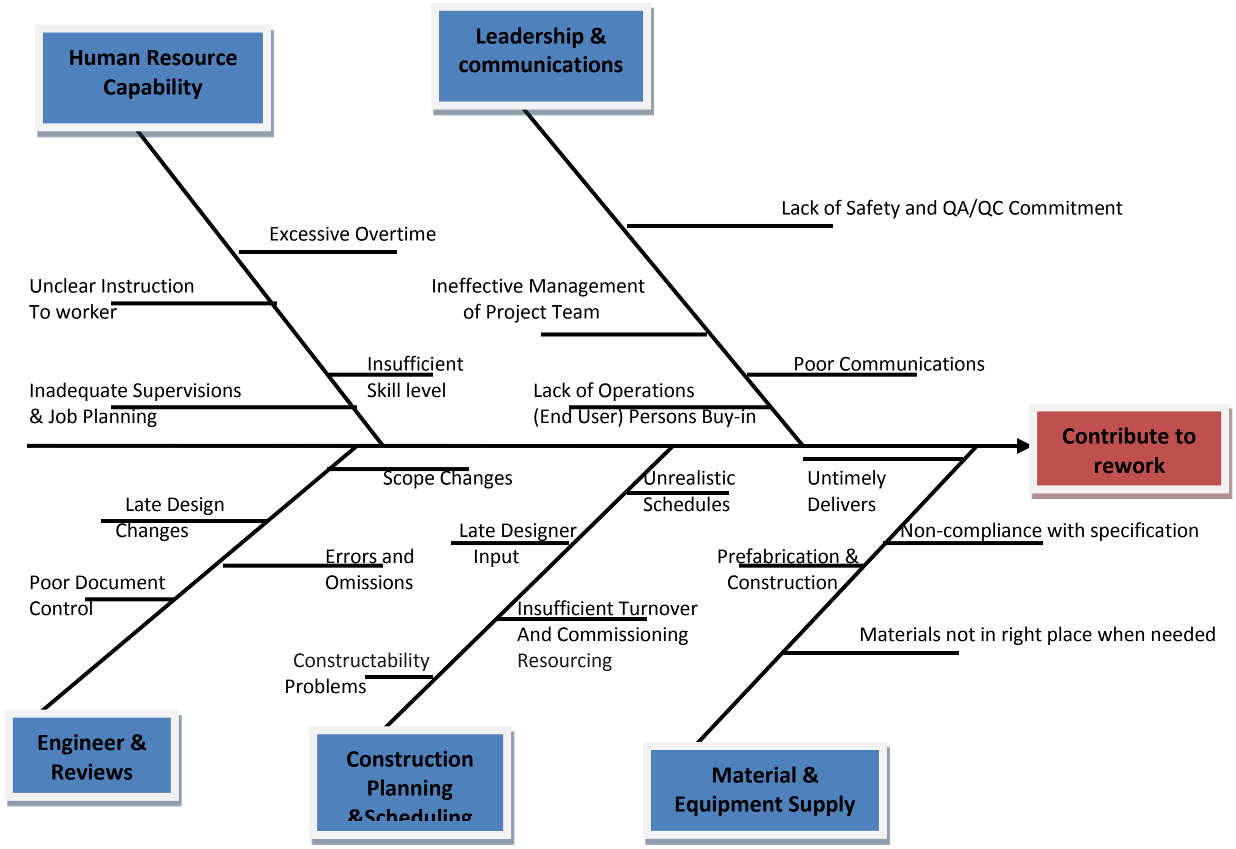

Figure 4: Rework Classification (fishbone) (Ruwanpura et al. 2003)

2.5 Impact of Rework

The presence of rework in construction projects clearly has an adverse effect on the overall project performance. As it has discussed in the sub headings below, the impact of rework cut across time, quality and the cost of the construction work and this result in a reduction in project profit, diminished organization reputation, brings about conflicts and loss of future contracts (Love 2002b). When considering all these factors, it can be concluded that rework has great impact on the overall cost of an undergoing project or expected future projects. The differences observed in the definition of rework by researchers based on the collection of data and methods used, signifies that the extent of rework costs could be far greater than what has been reported in the available literature (Love and Smith, 2003)

2.5.1 Overview of Cost of Rework

The significant impact of rework on a construction project in terms of schedule delay has made companies consider measuring the cost implication of rework on the total construction project cost. Significant researchers have looked in this direction for example, Rogge et al. (2001) identified that in the North American construction industry, a major way of tracking the field rework is by the use of quality performance management system (QPMS), and sometimes an internal proprietary tracking system. According to the Construction Industry Institute (2003), they propose a benchmarking and metrics program that advocates the following index to measure the amount of field rework for benchmarking purposes:

[1] $$\text{Total field rework factor} = \frac{\text{Total direct cost of field rework}}{\text{Actual construction phase cost}}$$

Many researchers have investigated the cost of rework in the construction and engineering industry. Table 4 shows the significant work carried out by the researchers which was adapted from Love & Edwards (2004). Only numbers that represent rework are shown. A major study that was carried out using nine engineering projects, by Burati et al. (1992), found that rework was based on what was termed "quality deviations" and rework in this respect accounted for an average of 12.4% of the contract value. Other research conducted by 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. Similar research conducted by 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. Based on these studies, an implementation of quality policies in an organization revealed that cost of rework can be reduced to 1% of the total construction cost if continuous improvement strategy were adopted.

In a related study, Azhar et al. (2008) explains that the issue of cost overrun has been a reoccurring problem in many projects undertaken by the construction industry. In understanding the key factors to project success, they stress that cost has its topmost contribution in that regard. While examining the fundamentals of a project, Elchaig et al. (2005) declare that factors revolving around projects are majorly qualitative, i.e. issues relating to supervisory roles, planning methodology, and selection and procurement procedures.

Avots (1983) defines cost overrun as the incurred excess on the budget cost of a construction project. The severe consequences of cost overrun have been greatly experienced in developing countries which make Angelo and Reina (2002) stress that the problem of cost overrun needs to be studied in greater details.

Table 4: Amounts of Rework in Projects adapted from (Love & Edwards, 2004)

No	Author	Country	Cost
1	Cusack (1992)	Australia	10% *
2	Burroughs (1993)	Australia	5% *
3	CIDA (1995)	Australia	6.5% *
4	Lomas (1996)	Australia	>1% *
5	Love et al. (1999)	Australia	2.4% & 3.15% *
6	Love (2002)	Australia	6.4% *
7	CIDB (1989)	Singapore	5-10% +
8	Hammarlund et al. (1990)	Sweden	6% +
9	Josephson & Hammarlund (1990-1996)	Sweden	2.3-9.4% *
10	Josephson et al. (2002)	Sweden	4.4% *
11	Burati et al. (1992)	USA	12.4% +
12	Abdul-Rahman (1993)	UK	2.5-%% *
Remarks: + = % of project costs *= as a % tot Total Contract Value			

2.5.2 Impact of Rework on Quality Cost

A general consensus reached based on the various studies shows that reducing rework in a construction project reduces the impact on the total cost of construction. However, rework cost has been translated to mean quality costs, and thus, one type of measurement designed to help the management with sufficient information about process failures and obtaining designed activities to prevent or reduce rework in construction project is based on quality cost approach. Love et al. (1998) define rework costs as the total cost accrued from problems of products or services before and after it was delivered. Thus, it was expressed that one of the ways to measure rework costs is to consider items including rework, material waste, and warranty repairs. This has been proposed by Feigenbaum (1991), who classifies cost to include failure, preventive and appraisal cost. These are one of the ways of examining quality costs. Such costs can be classified as the cost of conformance and the cost of non-conformance. It was expressed that conformance costs include cost of training, indoctrination, verification, validation, testing, inspection, maintenance, and audits. Alternatively, cost of non-conformance relates to cost of rework waste materials, and the warranty repair cost acquired by the company. All these were put together by Feigenbaum (1991), who classifies these costs of failure, prevention, and appraisal as cost of control and cost of failure control depicted in the Figure 5 below:

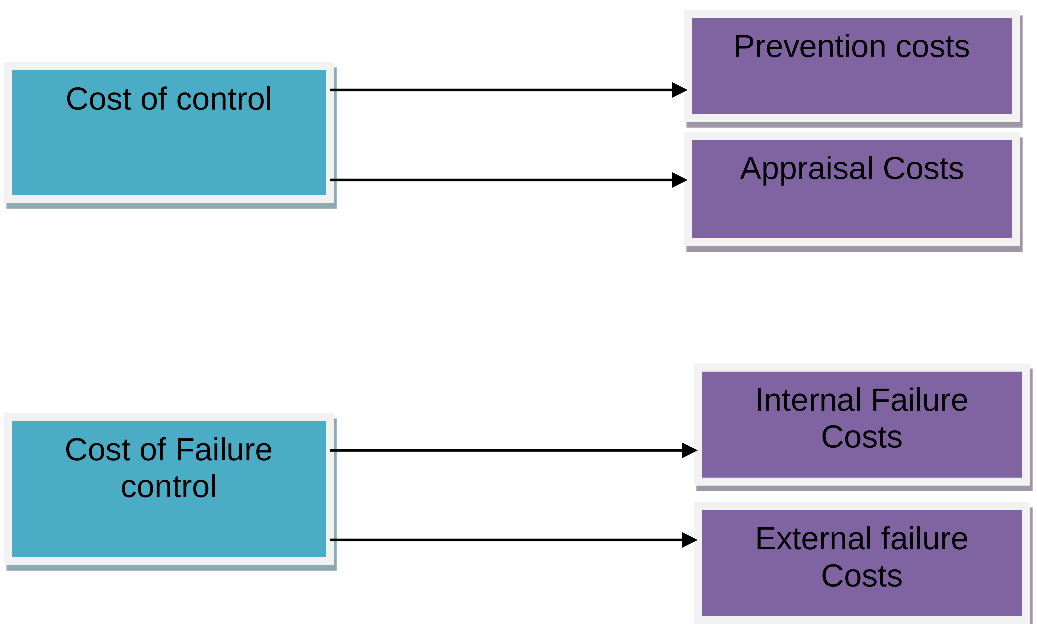

Figure 5: Quality Cost: Cost of Control and Failure (Feigenbaum, 1991)

2.5.2.1 Failure Cost

Failure cost can be internal and external. It was explained that the internal failure costs are those costs which are meant to resolve error or defect within identifiable measures set up by the organization. On the other hand, external cost dealt with costs that are not in conformity with the client agreement.

2.5.2.2 Appraisal Costs

This has been identified as the cost spent on detecting error or defects in construction work by measuring the level of conformance to the client's design specifications. This includes ensuring proper engineering and structural drawings, work in progress, assessment of incoming materials and ensuring finished work is acceptable.

2.5.2.3 Prevention Costs

The cost of prevention is the cost invested to prevent the occurrence of the error or defects taking place in the first place or cost expended to ensure the absolute reduction of error or defects from occurring in the construction work.

An earlier research by Campanella and Corcoran (1983) explains that increasing the finance expended on prevention and appraisal cost will bring about a reduction in the failure costs over time of its implementation. Failure costs on the other hand are almost avoidable. Eliminating the causes of rework will drastically reduce the appraisal cost (Low and Yeo, 1998). It is on this basis that a number of researchers place more weight on cost associated with rework. Woodward (1997) stresses that rework accounts on average 10% or greater of the total project cost.

2.5.3 Impact of Rework on the Project Cost Performance

Love and Edwards (2005) carried out a national questionnaire survey in Australia and identify two categories that result to total cost of rework, as direct and indirect rework cost. Although a lot of research has been conducted to determine the significance of direct cost on rework, exploration into the indirect cost of rework has been minimal. This is due to the fact that it is quite difficult to quantify in its absolute (Love 2002b).

2.5.3.1 Direct Cost of Rework

In a research study by Love & Sohal (2003) emphasis were placed more on finding how much percentage are associated to direct cost with respect to rework in the overall contract value (Love & Sohal, 2003). Other study carried out by Love & Li (2000), found that the direct costs in residential and industrial building were 3.15% and 2.40% respectively on an account of the rework associated in both cases on the total contract value of the projects. Similarly, Love and Li (2000) revealed that on large projects such as the civil and heavy industrial engineering projects, it was found that the total contract value related to direct cost was on average 12.4 %.

The direct costs associated to rework as identified above show that additional costs from rework have a substantial adverse effect on project performance. Although, the effect of cost associated to project performance, the additional time required to redo the work would also result in a time shift or delay and would affect the project schedule. Tommelein, et al. (2007) states that the direct rework cost includes man-hour, schedule, equipment, materials and the required space used up in the cause of the project.

Furthermore, Palaneeswaran (2006) explained that calculating the impact of direct cost in a construction project should be viewed from the start of additional time spent on redoing a given task, extra cost needed to cover the expense of the rework task, supplementary materials used up for the rework and the additional labor force and supervisory efforts needed to cover the rework.

In a study undertaken by the Construction Task Force in UK estimated rework in construction work could rise to 30% (Egan, 1998), and an associated cost of this rework as high as US$15 billion could be the resultant loss of a construction project expanded on rework (CII, 2001a). The gravity of rework is also felt extensively in the quality (cost), overheads (Indirect cost) and upon all the resources associated (Love and Edwards, 2004).

Similarly, as mentioned earlier in the classification of rework, Fayek et al. (2003) carried out a study in Canada on a total number of 108 field reoccurring incidences and found out the cost contributions on the followings; engineering and reviews (61.65%), human resource capability (20.49%), materials and equipment supply (14.81%), construction planning and scheduling (2.61%), and leadership and communication (0.45%) were as a result of rework.

2.5.3.2 Indirect Cost of Rework

Love et al. (2002a) revealed that indirect cost of rework cannot be readily worked out as the cost spread across the following: loss of schedule and the productivity, litigation and claims, and low operational efficiency but could be five times higher than the cost of modification (Love 2002b). Similarly, Tommelein et al., (2007) stated that indirect cost of rework is a combination of the construction performance factors, the extent of attainable coordination, and network impacts. In a study conducted by Love (2002b), it was revealed that the significant cost incurred in indirect cost of the organization was via the extension of its original contract duration of the construction work, and this affected the organization's capacity to pave way for other new contracts. This was a situation in which the organization had to cope with by adding extra resources and payment of extra cost as a result of overtime.

Further, other areas focused on by researchers are the indirect consequences of having rework in construction. Love (2002) noted that rework brings about psychological degeneration on the part of the organization workforce as shown in Figure 6 for which monetary value cannot be attached.

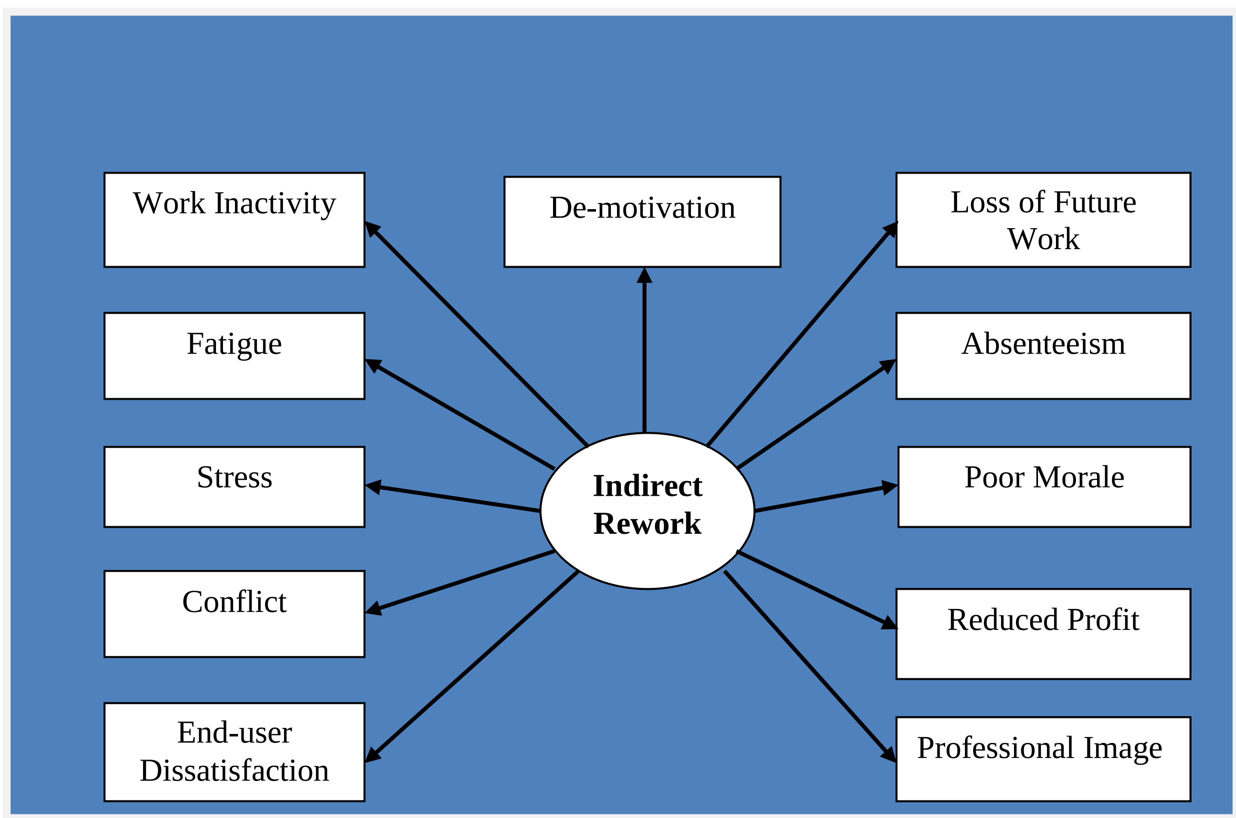

Figure 6: Taxonomy of the Indirect Consequences of Rework (Cooper, 1993)

Another contributing factor that has been found to be a major contributing factor to rework is defect cost. The defect cost has been defined as the resources value embedded in the performance of rework as a result of the detection of defect **(**Josephson 1998**)**. A large amount of time, materials and equipment are used up in correcting defect. Defects could result from all concerned in a construction project, and is calculated irrespective of who undertakes it. As earlier defined by (Josephson and Hammarlund 1999), rework could be said to be a 'defect', further, distinction based on direct and indirect defect (failure) cost has equally been explained above. Harrington (1987) declares that indirect defect costs are related to cost incurred by the customer, dissatisfaction cost of the customer, and this usually brings loss of reputation cost due to the occurrence of defect experience.

2.5.4 Disruption of cordial relationship

Another very serious consequence of rework in the construction industry is the loss of reputational goodwill. Love and Edwards (2004) agree that a major setback encountered with frequent reoccurrence of rework in the construction project makes the organization lose its industry reputation. Endut et al. (2005) studied the dissatisfaction of rework implication in the construction industry and concluded that it was a problem that needs to be addressed in order to avoid tarnishing the glory of the company involved, and incurring loss of future business and reduction of company profits.

2. 6 Rework Model Analysis

There have been some documented ways by which rework can be tracked. Fayek et al. (2003) proposed a model on the field rework as shown in Figure 7. In the proposed study, the field rework is initiated once any form of rework attributes has occurred on the field, and subsequently identified. In the model, the supervisory role identify the rework and report it to the appropriate level of authority in order to obtain a directive on what is needed to be done. Detailed gathering of information was encouraged, such as event of occurrence, time of event, labor working at the time of incidence, type of equipment used, cost of the material and the cost of the subordinating handling the operation. These types of information are gathered for every observed rework occurrence. Subsequently, the data are put together as the total direct field cost of rework as shown below:

$$D_r = \sum_{i=1} L_{r\,i} + E_{r\,i} + M_{r\,i} + S_{r\,i} + V_{r\,I} \text{ ....equation 1}$$

D_r is the total direct field cost of rework, L_r is the direct field labor and supervision cost of rework, E_r is the direct equipment cost of rework, M_r is the material cost of rework, S_r is the subcontract cost of rework, V_r is the vendor and supplier cost of rework, i is the rework event n is the number of rework events.

Further, the construction field rework CFRI is now calculated using this equation;

$$CFRI = (D_r * IF) / [D+I+P+Q] \text{ ....equation 2}$$

Where D is the direct field construction phase cost, I is the indirect field construction phase cost P is the profit fees (CAN$), Q is the overhead fees (CAN$), D_r is the total direct field cost of rework, CFRI= (total direct plus indirect cost of rework performed in the field)/(total field construction phase cost).

Although, the model has stated processes of tracking rework in a quantitative sequence, but there has been emphasis placed on qualitative approach in evaluating the causes of rework as noted by (Josephson 1998; Dew, 1991; Wilson et a., 1993).

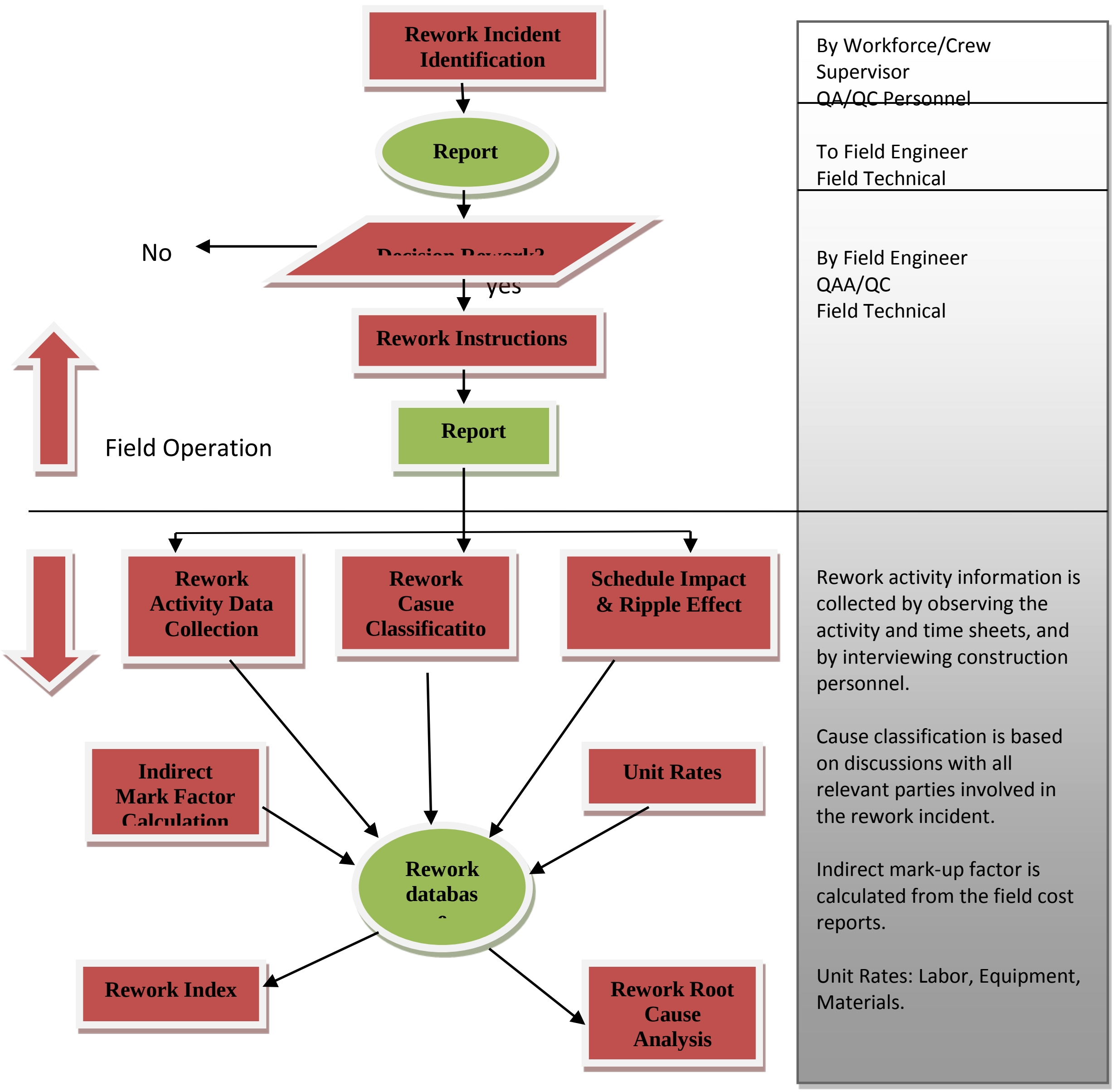

Figure 7: Pilot Study on Field Rework Tracking (Fayek et al. 2003)

Chapter 3.0: Methodology

Chapter 3.0 Methodology

The research design for the study is discussed in this methodology chapter. It explains the approach by which the data for the study was collected and the structure in which the research study will be undertaken.

3.1 Research Design

This research studies the causes of rework and the impact of the rework on the construction project to the overall total cost of project. The proposed hypothesis in the introductory chapter of this study assumes that the underlying problems of rework as reviewed by previous researchers can be grouped under three factors: people, process and technology. As such, it shows that a very close interactive relationship is expected that could impact on the total project cost and project performance. According to Robertson et al. (1990), the best way of making inquiry is through interviewing the participants involved in the case, as this will give the interviewer an in-depth knowledge into the situation leading to the occurrence of the problem. Further, interview is a systematic investigative approach of ascertaining the factors surrounding the decisions taken by the participants. Looking from a dictionary point of view, the Concise Oxford English Dictionary (COED 2004) defines interview as the systematic investigational approach of studying people in order to gain insightful facts concerning the occurrence of a problem and establishing cognitive evidence as to why such a problem as occurred, and thus, by so doing, a new conclusion is reached. Similarly, Burns (2008) expresses that the principle of inquiry is a systematic approach for answering a problem definition. The research design covers the scope of the study to which the research has been confined. Additionally, the method of collecting the data and mode adopted to make inquiry into the cause of rework in the construction project are covered in this chapter. According to Bell (2005), the methodology of a research study is critical to the success of any research work, as the vital details of its framework are expected to be elaborated in such study. An important point noted by the researcher is that the methodology of collection data is crucial to finding a viable solution to the underlying problem posed in the study (Leedy and Ormrod 2010). In this light, the research study has taken the approach of being pragmatic in presentation by following four fundamental principles of sourcing the facts (i.e. data and information) as delineated below:

What types of data are needed: This refers to the data source for verifying the extent of overruns in the total cost of construction work of the studied pipeline project. This will include the factors causing the rework in the project and the associated cost impact it will effect on the total cost performance of the project.

Where the data will be obtained: This indicates from where the data will be obtained. In order to get the data for this study several employees were interviewed from both the contractor and sub-contractor involved in the project such that rework became necessary.

How to obtain the data: A method of ensuring that the approach adopted will capture the needed factors to determine and solve the research problem must be adopted. In this study, a qualitative research was adopted.

How to ensure an accurate interpretation of the data: Information gathering would follow a particular pattern of analysis as recognized by the researcher.

In view of these explanations, the research study has adopted an inductive qualitative approach in the investigation of the root causes of rework on the construction project.

3.2 Qualitative Research

Qualitative research as defined by Creswell (2009), states that it is a social related method of inquiry into a problem that is in line with the developed conceptual framework of the research study. Leedy and Ormrod (2010) stress that qualitative research is a way of examining the characteristic of human factors leading to the cause of a problem, such as those reviewed in the literature section. As it has been discussed earlier in the literature review of this research, researchers conclude that the defects, omission or error that occurs in construction work usually manifests from the clients, main contractors, are sub-contractor related, are predominantly the result of people, the process and the technology as has been conceptualized in the framework. Further, qualitative research has been classified to be exploratory research in nature, where observations of the root cause(s) of a problem are used to build up theory (Leedy and Ormrod 2010). Similarly, Gummesson (1991) depicts that data that are put together from the basic are used to analyze situations which could be used for future research. A recognized form of reporting qualitative research was proposed by (Creswell 2009). Creswell characterizes qualitative research as follows:

- Collection of data at the sites where the problem was experienced and with the participants involved.
- Method of inquiry and collection data in qualitative research comprises documentation, behavioral observation or interviewing participants.
- Qualitative research relies on various forms of data collection rather than to limitation to a single point data source.
- The researcher in qualitative research keeps focus on the problem at hand during the process of making the inquiry.

Thus, in this research study, in order to determine the root causes of the rework in the existing pipeline construction project, coding of the interviews was employed done to extract those factors that led to the rework on the project.

3.2.1 Coding in qualitative research

According to Anselm (1987), the quality and value of qualitative research lies in its excellent way of coding the data into category, such that working with the themes developed, will form a new cut of the data that are used to resolve or address the research problem. Furthermore, (Patton 2002) stresses that choosing the “right tool for the right job” is essential to accomplish the resolution of research problems, research questions, conceptual frameworks and the generated field data, since those problems are context-specific based. What then is coding? Coding in qualitative inquiry is expressed as a short word or phrase used to capture the salient feature in a language-based text (Saldana 2008, pg 3). It is assumed that the data can be the result of the transcription of an interview that was conducted in the reason for the study, notes observed from participants, journals so on. The processes of coding are usually done in cycles, depending on the magnitude of the study, and are classified as descriptive, In Vivo, and Initial coding (Saldana 2008). The research study is expected to follow the important rules of understanding the pattern and regularities of the data (Agar, 1996, p.10). It was further expressed that the coding could be categorized based on the settlement of the participants. However, Hatch (2002) proclaims that patterns should not be assumed to follow a stable regular pattern but is in fact, in varying forms. Thus, patterns are characterized as follows: similarity, difference, frequency, sequence, corresponding and causational. This type of analysis was employed in the transcription of the interviews conducted with the research participants for the purpose of the research study.

3.2.2 Importance of coding

Coding allows new themes to emerge which are developed from the transcripts of the interviews. The emergence of these themes is identified in order to correlate the findings of the interviews with what is being researched. According to Elliott and Gillie (1998, p.331), the importance of coding helps the researcher to identify the similarities and differences across the varying groups that are interviewed. Using coding in qualitative research enables the use of a guided methodology in the evaluation of the research objectives to be achieved. Furthermore, coding ensures the reliability of the data collection and ensures the validation of the data when carried out by other researchers.

3.3 Research Participants

To be able to carry out the research study, many of those involved in the construction project have been interviewed in order to have a deeper insight to the problem necessitating rework on the on-going project. The participants are mainly from the main contractor and include the site engineers, project manager, and supervisors, (10 interviewees). 13 from lower cadres working on the project directly were similarly interviewed, including the site technician, foreman, operators, and the drivers. In all, the total number of interviewees was23; it was necessary to interview many of the concerned as this would give the right direction to the nature of the problem and ultimately lead to the root cause(s) of rework as aimed in the research study. Further interviews were held with the financial manager and the document controller in order to find whether there were measures in place for detecting cost impact of rework. To a very large extent, these are significant steps needed to inquire into a root cause of a problem as exemplified in the research work by (Robertson et al. 1990) principles of inquiry.

3.4 Data Collection Methods

Collection of data has been done through two different approaches. One approach was to look into relevant authors who have written textbooks on the issues of rework in construction projects, accessing related relevant journals, conference release on rework in the construction project, and so on. This was categorized as secondary data sources, and has been done in such a way that only the relevant ones were evaluated with respect to the study at hand as proposed by (Stewart and Kamins 1993) when using secondary data in research study. Stewart and Kamins (1993) explain that the relevance of the data must tend towards addressing the problems of the research study, serve to strengthen or illustrate the diverse views of researchers on the intended study and perhaps, operate as a guide line to the method of collection of the data. Furthermore, the reviewing of earlier studies of other researchers in a given subject area on the basis of its descriptive and analytical format makes it possible to view the similarities and possible contradictions on such a research work (Naoum 1998). Other researchers have mentioned the need of a preliminary and full study of other researchers work (Melville and Goddard 1996). Thus, in this study sources relevant to the rework, its origin, main causes, classification, and its impact in the advent of its occurrence has been reviewed. While on an elaborate scale, views of researchers on the causes and cost impact of rework in the construction industry was depicted. Nevertheless, primary data have been obtained for the purpose of investigating the root causes of the problem into rework on n a huge pipeline water construction project in Libya. This includes the interviews conducted with the workers of the main contractors, sub-contractors and meeting with the financial departmental head of the main contractor to collect the financial data in order to evaluate the cost impact of rework to the overall project cost. An account related by Leedy and Ormrod (2010) claimed that the best form of validating information or data is via the primary data. By so doing, two forms of primary data were conducted to ensure that the research study addressed the aim of the research study, which comprised interviews and collection of written documents on financial data so that both the root causes and the cost impact of rework could be properly investigated, along with its corresponding influence on the project's performance. Walliaman (2005) explains that primary data should be collected directly, with a clear observation within the context of a real world that is undisturbed by any prejudice, thus forming the basis of an exploratory research of the study. Neuman (2000) states that exploratory research is research conducted to look into an area of study where new ideas can be developed that will address the underlying reason for carrying out the research study. To this end, this research made use of semi-structure interviews, observation of site situations, review of the non-conformance report (NCR), which is the site reports and collection of financial reports of the project's progress. This data would be used to develop the classification of information needed to investigate the theoretical hypothesis of the research study.

3.4.1 Interviews

Interviews as described by Rubin and Rubin (1995) are conversation between two or more people that is guided on the basis of an inquiry into a study being made, and can take the form of a rigid or a fluid pattern. In an earlier definition, Best (1981) viewed it as a discussion that involves two or more people, usually called an interviewer and interviewee(s). To uncover the reason for conducting an interview, Wimmer and Dominick (1994) stressed that a successful interview unveils the perspectives of research participants with respect to the aim of the research study. Further, the interview is expected to serve as a means of gathering information, making a direct observation of the issue at hand, and form the basis upon which hypothetical assumptions are tested (Best 1981). In this research, a semi-structured interview has been used. This form of interview was adopted in order not to limit the participants to the researchers' views but also to be able to get an in-depth reason from those that were being interviewed. A semi-structure interview is a bridge between the structured and unstructured interviews. Fellows and Liu (2008) declare that there are many forms of semi-structured interviews ranging from a questionnaire to a probing form of questions set or prepared to investigate the root cause of a problem. Relevant participants have been interviewed in this research study and include the project manager, site manager, site technicians, supervisors, operators, foreman, drivers etc. The interviews were taped and transcribed for onward categorization of the investigating facts via coding.

3.4.2 Observation and review of NCR

Direct observation of the situation at the construction site was carried out by the researcher in order to observe the extent and see the reason why such facts emanating from the interviewed participants resulted in rework in the ongoing project. This was essential for this research study, as numerous factors might be the cause of the rework occurring in the project; this could include behavioral and climatic factors, tight regulations and so on which might be difficult for some of the research participants to communicate. The NCR is the site reports originating from the client claiming non-conformance of work done at the site with the signed contract. A total number of 50 NCRs were collected and this serves as the basis of examining the root causes of the rework on the project.

3.4.3 Financial Data

The financial data are the data that ensures the researcher is able to evaluate the impact of rework on the on-going project, although this has been very difficult to collect; nevertheless, the cordial relationship that was built up with some key members of the main contractor gave the researcher the opportunity to meet with the financial manager to obtain certain confidential information which was meant solely for the research purpose.

3.5 Data Analysis

In this section, the methods of analyzing all the data collected from the construction site are explained. Firstly, the research methodology being an inductive qualitative approach, the method of analyzing the interview was done via an inductive coding. It begins with a close reading of the transcripts of the interviews and deriving multiple meaning(s) that are embedded therein in the text. Thus, useful identification of segments containing units of meaningful themes is formed, although the approach follows a cyclic pattern in which at the initial stage, collection of descriptive items are formed into categories and are associated with links. Furthermore, these links are later re-categorized to form various relationships that come in the form of network, hierarchical order or patterns. According to Hatch (2002), these patterns do not have to be stable, but may come in varying forms and can thus be characterized as similarity, difference, frequency, sequence and so on. On this basis, Tesch (1990, pp. 135-8) acknowledges that the construction of category in qualitative inquiry on the data may not necessarily be precise but may be confounded within a fuzzy-like frame at best. In order to ensure focus on the study that will address the aim of the research and test the proposed hypothesis, Charmaz (2003) pointed out the following must be ensured during the coding:

- What is the sequence of events?

- What are the participants involved in?
- What are the participants saying?
- What do the actions and inactions of the participants take for granted?
- How does the structuring of the context depict the impeded actions?

An encapsulation of the coding process was outlined in Creswell's (2002) work. Table 5 shows the sequence of the process outlined. As delineated in the table, the process is such as to capture the key concepts relating to the objectives of the research findings from the raw data. Thereafter, it is being assessed as the main cause of rework in the on-going construction project.

Table 5: Showing the process of coding in an inductive analysis

Initial reading of Text data	Identify specific text segments related to Objectives	Label the segments of text to create categories	Reduce overlap and redundancy among the Categories	Create a model incorporating most important categories
Many pages of text	Many segments of text	30 to 40 categories	15 to 20 categories	3 to 8 categories

The second analysis is based on calculating the impact of the rework in the construction project to the total cost of the project. The collected NCR data for the site report on rework are checked and the amount the rework is correlated with the actual cost of the work. The principle follows the formula deduced by construction industry institute (CII) bench marks and metrics program (2003) in the estimation of cost of rework as given below:

$$\text{Total field rework factor (TFRF)} = \frac{\text{Total direct cost of field rework}}{\text{Total construction cost}}$$

The outcome of these findings will be reviewed against similar research findings relating to construction project studies done in other research. Appendix I shows studies that have calculated cost of rework across projects and the impact of the rework is described in percentage.

Azhar et al. (2008) declares that cost overrun in construction project has become a frequent phenomenon that has called for attention. This is necessary as cost has gotten a large impact on the success of the entire project. However, those cost overrun incurred in a project is largely as a result of rework, which can be addressed. The research study examines the causes in the pipeline construction project and calculates the percentage ratio associated to rework in the on-going project on the basis of the identified categories of concern to the project. The planned cost details and the actual cost of the project progress financial report received from the financial departmental head plays a large role in this regards. The frequency of each identified rework categories were obtained from the NCR data that were obtained as a result of non-satisfaction of the client's objectives. This enables the research study to identify areas where much of the rework lies and helps to channel interview questions in that area. Also, the categorization of the frequency of the rework equally helps to determine the number of times such rework occurred, and this helps to determine the amount of cost associated with such type of rework. It is important to note that the frequency has been denoted with numerical value ranging from 0 to 5, with 0 as the minimum number of times the rework occurred while 5 signifies the highest number of times the rework has occurred.

Summary

The investigation into the root causes of rework using an inductive qualitative approach achieved via the coding of the interviews and examining the cost impact of rework in the on-going construction project serves as a means to verify the initial logical supposition posed in the hypothesis of the research study. As stated by Leedy and Ormrod (2010) an in-depth understanding of the research hypotheses will emanate from the sub-problems, and a closed corresponding frequency upon which the sub-problem lies. Thus, hypotheses may either be supported or proven not to have any relationship based on the initially posed assumption.

Chapter 4.0: Research Discussion and Analysis

Chapter 4.0 Research Discussion and Analysis

4.1. Introduction

This chapter deals with the research discussions and analysis of data for the research study. It covers the analysis of the data collected via non-conformance reports (NCR), financial data and the interviews which are meant to investigate the root cause(s) of the problem into rework experienced in the on-going pipeline construction project, and also understand its impact on project performance, and to determine the percentage of rework on the total project cost. The next sections address the research focus.

4.2 Data Discussion

The section discusses the data of the research study starting with the non-conformance reports that were collected from the contractor quality department; this is followed by the interviews conducted with the research participants and, finally the financial data of the project progress. Details of these are given in the sections below:

4.2.1Non-Conformance Report (NCR)

The NCR is a report that focuses on the non-conformity of the contractors work to the agreed contract specification. It is usually reported by the client representative assigned to monitor the progress of the project. The NCR signifies something that has gone wrong, which needs to be addressed. It is often reported with the acceptable corrective action needed to remedy the error. In this research study, a random sampling of 50 NCR’s of the ongoing pipeline project was obtained from the site manager. The NCR has been collated based on the clients request to amend or correct the defective area of the project that does not meet specification or the requirement of the project. Table 6-11 shows the extracted descriptions of non-conformance reported in the project. Although the NCR’s included the following, item descriptions, item Number, disposition proposal, apparent cause among others, the focus was on the non-conformance and the number of times of occurrence of such error in the project.

Table 6: Shows the non-conformance descriptions for haul road

S/N	Category	NCR	Description	Frequency
1	**Haul Road**	1a	Oversize materials were used during the general fill for the haul road construction	7
		1b	Soft spots identified on haul roads	6
		1c	Borrow pit materials were used during haul road construction	5

Table 7: Shows the non-conformance descriptions for excavation

S/N	Category	NCR	Description	Frequency
2	**Excavation**	2a	Depth of excavation does not meet requirement	3

Table 8: Shows the non-conformance descriptions for pipe transportation

S/N	Category	NCR	Descriptions	Frequency
3	**Pipe Transportation**	3a	Pipe damage during transportation (Spigot groove)	2
		3b	PCCP damage during transportation	1
		3c	PCCP pipe (external & internal mortar cracks) During unloading	1
		3d	Spigot ring damage during unloading	2

Table 9: Shows the non-conformance descriptions for pipe installation

S/N	Category	NCR	Description	Frequency
4	**Pipe Installation**	4a	Pipes need cleaning during installation	2
		4b	Spigot damage during the pipe layering	3
		4c	Pipe pushing machine got broken, cracking the pipe	3
		4d	Pipe cover depth does not meet specification	2
		4e	External mortar crack damage during pipe layering	3

Table 10: Shows the non-conformance descriptions for back fill

S/N	Category	NCR	Description	Frequency
5	**Back fill**	5a	Back fill soil compactness does not meet requirement (i.e. Structural backfill test)	3
		5b	Earth pressure test shows that subsurface pipes are prone to damage	3

Table 11: Shows the non-conformance descriptions for concrete work

S/N	Category	NCR	Description	Frequency
6	**Concrete work**	6a	Uneven concrete gap in between pipe installation causing faulty Air test	3
		6b	Concrete rings test shows that manholes cannot withstand dynamic forces	1

The NCR's has facilitated the researcher to categorize the main project structures, and six areas of the project have been identified which include the haul road, excavation, pipe transportation, pipe installation, back fill and the concrete work (i.e. manholes). In order to gain insight of the project categories and terminologies, a brief explanation of each term has been described below:

Haul Road

The haul roads are constructed for use by large and expensive trucks. It uses an empirical design method, which may not necessary result in an optimum road design. The functional haul road covers 380 km in distance and needs a reliable wearing course to avoid damage to large trucks. It was agreed for construction as per the contract requirement to reduce inefficiency of the trucks, increase road usage and maintain the life-span for the trucks. Thus, this has called for selective materials to be used in the construction of the haul roads, needing special attention paid to density of materials (i.e. soil compactness), and dust ratio and particle size distribution.

Pipe Transportation

The pipe transportation involves the transportation of pipes from the pipe factory to the point of their usage across the whole length of the pipeline project. The transportation of the pipes is made along the haul road, and since the pipes are made of concrete, they are prone to cracks or total damage if the slightest external pressure is impact on them. Thus, this calls for an experienced driver; safety measure procedures, and a well constructed haul road among others to enable the successful achievement of this operation.

Excavation

This is the trench dug in readiness for the laying of the pipes. During excavation, it is necessary to prepare for how to handle; store, transport, and even dispose of the excavated earth materials in such a way it does not result in unnecessary rework to activities that have already been completed. The excavation for this pipeline project is expected to be 7 meters in depth and 5 meters in width, and done in such a way that it will not result in the collapsing of the walls or exceeding the required depth and width as this would amount to using more materials than necessary. During the excavation process, three main phases might be encountered and should be prepared for; normal, blistering and dewatering. The normal excavation is the process of excavating without encountering any foreign earth materials such as rocks, limestone etc. Blistering involves breaking hard solid earth materials by means of an explosive material and special equipment to facilitate the excavation of the earth materials. Lastly is the dewatering, and entails the removal of water from the area of the planned excavation site. A successful accomplishing of the excavation work requires an experienced workforce, special equipment and proper planning and monitoring.

Pipe Installation

The pipe installation entails the laying of the pipes beneath the soil surface at a depth of 5 meters from the ground surface, and thereafter, back filled with 1 meter of compacted sand. The laying is done in a sequential order considering the slope of the flow of the water. The pipes are of 75 tons each in weight and need to be handled with care. The laying of the pipes needs special heavy cranes which require operation by an experienced crane operator, and a significant amount of advanced machinery is required during the installation process.

Back-Fill

The back-fill involves the filling of the installed pipes with reinforced gravel. This is needed to facilitate the redistribution of some of the load away from the pipe and into the side-fill soil. It is important to ensure the trench backfill is placed back on the pipes in a compacted form at a level 2 meters below the pipes and 1 meter above the installed pipes, as per specification.

Concrete work (Manholes)

The manholes as per requirement are expected to be placed at 5 km from pipelines. The manholes structure serves as the principle access point in the system maintenance of the pipeline construction. The manholes for the pipeline work have agreed height and diameter measurements of the frame which needs to be adhered to. Each manhole is expected to have a physical description that will facilitate the subsequent phase as the project progresses. Depending on the installation pipes' area, cathode protections are installed to prevent the pipe from aggressive attack by corrosion.

As indicated in Table 12, it was obvious that what led to rework in the ongoing pipeline project had not been addressed as there are quite a number of factors that reoccurred more than once. Based on the information derived from the 50 detailed NCRs, a semi-structured interview was conducted with some main contractor workers, subcontractors, and departmental financial heads to look into the root cause(s) of the problem for those rework activities taken place at the site. The next section discusses the outcomes of the interviews that were conducted.

Table 12: Shows Categories by Rework Frequency

Category of rework	Total frequency	Ranking
Haul Road	18	1
Pipe Installation	13	2
Back fill	6	3

Pipe Transportation	6	4
Concrete	4	5
Excavation	3	6

4.2.2 Interviews

This section presents some interviews that were conducted with some of the field workers at the ongoing pipeline project. A total of 23 interviews were conducted as shown in Table 13. The interviews were aimed at finding out the root cause(s) and impacts of the rework that resulted from the main structural areas of the pipeline project as observed from the NCR's categorization, the influence of human resource capability, quality management practices on the occurrence of rework, and were conducted in such a way that the participants could share their own points of view with respect to the problem, while noting the impact of the rework through observation and analysis of financial data collected thereafter. The interviews were conducted with relevant parties who were working at the site and directly involved with the operations of the project. A time limit of 40-50 minutes was given to each participant, and the interviews spanned a period of three weeks. The set of semi-structured interview questions reflected some factors that have been identified from the literature review, factors observed from the NCR's, research objectives, and a host of other questions to ascertain answers to the hypothetical questions that were formulated in the introductory chapter. It should be noted that the researcher took the time to note the responses of the participants, as it was initially observed that some of the participants were not at ease with the interview being taped, and as such the researcher resorted to noting their views on a written document which made the participants express their views extensively having been promised that their identity will remain anonymous. These conditions are very understandable as the project was still an ongoing project and many feared losing their jobs. The interviews conducted then, were noted in written document format, and thereafter, a segmented coding was performed.

Coding qualitative data

In this research study, a hierarchical coding structure of the text was done. The written documents followed several codes that were grouped together as observed from the participants' interviews to be the root cause(s) of the rework experienced in the ongoing pipeline project. It follows that some codes were put into groups, while some were further sub-coded to reflect the main groups as shown in Table 14. The coding was done by marking the identified segments (i.e. descriptive words) of the data with alpha-numeric symbols as depicted in the section below and subsequently, the relationships between the codes were further grouped into themes that reflect the findings from the literature review with respect to the possible main causes of rework in the construction industry and was discussed under section formation of themes.

Foreman

I started working with the company and on this project for the last 11 months. I am responsible for the pipe installation team. I think the company had a good facility in terms of equipment and machinery, but the problem with the work was that the pipe installation is a very sensitive job and some of the laborers do not have enough skills and knowledge (*Line 4: erroneous workmanship*) (**A1**) to use the installation equipment (i.e. advanced heavy cranes) as there is no special training given to the operators (*Line 6: training on machines*) (**B2**). Many have little knowledge of operating those machines before, which might have given them the opportunity to work on this type of project in the first instance, but it showed that some intrinsic parts of the operation were being learnt on site while performing the task (*Line 9: faulty work preparation*) (**B1**), so there are some mistakes that have to be reworked. Coupled with that, there are quite a number of advanced machines that are being used at site such as the cranes and pushing machines, and they need some time for the operators to get used to them (*Line 12: difficulties in learn advance machines*) (**E1**).

Technician

I have been working with the company for more than 1 year as a technician. I worked with the pipe installation team as a punching machine operator. Sometimes we faced installation problems which cause pipe damage and this could be as a result of the following reasons:

Punching machine efficiency: - Sometimes we do not work with the support of a specialist at the final stage of fixing (*Line 5: difficult to use advance machine*) (**E1**).

Communication problem: - the team is made up of diverse people (i.e. different nationalities) like people from Arabian countries, Poland and Turkey, although we all communicate in a common language (i.e. English) but sometimes their accent in pronunciation might mean something else to another team member (*Line 9: language difficulties*) (**D1**), so as a result of that, some errors do occur and we have to work it again.

Crane Operator

I have been working with the company for more than 3 months as a crane operator. The difficulties which I sometimes face have to do with some functions of the crane. They tend to be a little bit more advanced than the ones I had experience with at my former company (*Line 3: difficulties to use advance machine*) (**E1**). Although I have more than 15 years of working experience, as a result of this technicality, I sometimes make mistakes, especially during the first two months I started working with this company. In that regard, I would rather suggest that the management provide training to newly employed staff (*Line 7: lack of training*) (**B2**) for sometime before being given the responsibilities to work on demanding projects of this nature. However, it might be that the company has more work to do; they would rather terminate an operator appointment and employ another person rather than to train and this has made many of us pretend that all mistakes were of the making from a faulty machine (*Line 11: faulty machines*) (**E2**). I think this is not good for the company.

General Labor

I started working with the company about 1 year ago as general laborer. I work with the excavation team and sometimes with the trench cleaning team. There are some challenges we face while working, some of which are made obvious when backfilling, perhaps due to the initial depth specification not meeting requirement (*Line 4: erroneous workmanship*) (**A1**). Honestly, the job is tasking and we are made to work longer hours (*Line 5: working long hours*) (**B3**) such that many are tired but we have to keep working, coupled with the climatic condition of the place we are working (i.e. very hot). Because the company pays us overtime, so many are always willing to stay behind even if they are tired, as for me, I work 12 hours daily and feel the fatigue at some point in time, but I need the money. I am sure this brings about some of the errors we make on the work. Our supervisors come only twice in the night shift and this is not enough to monitor the large amount of work that might have been covered (*Line 11: insufficient* *supervision*) (**A2**). Thus, when the client's consultant engineers carry out their inspections, they are always finding one thing or the other to write up as a complaint. Thereafter, we are called to rework the same work we have done before. It may be that the laborers are not enough, so the company needs to employ more staff (both laborers and supervisors) so that more people are at work to do the job properly.

Driver 'Trailer'

I have been working with the company for more than 2 years as a trailer driver. My duty as a trailer driver is to transfer the pipes from the manufacturing factory to the site. The main problem which causes the damaging of the pipes is during the transportation and a few as the result of off-loading the pipes. Most of the causes are due to the following:

Unclear visibility: This is due to dust from the road during transportation, especially at night.

High speed: I noticed that some of us usually speed during the transporting of those pipes (*Line 6: over-speed*) (**B4**) and not all the drivers have the same level of expertise.

Lack of safety rules: I noticed that some of the safety signs have been damaged and were not replaced (*Line 9: damage safety signs*) (**B4**), so sometimes the drivers do not stop where they are supposed to, or even pack were they are not supposed to park. These usually cause accidents.

Malfunctioning of trailers: Sometimes the trailer malfunctions (*Line 11: trucks malfunction*) (**E3**) which causes the drivers to lose control of the steering, which results in an accident which damages the pipes.

I would rather suggest the company should have sufficient maintenance teams that would carry out maintenance services as and when due, maintain the haul road regularly to relieve the drivers of the dust they encounter when driving, have a monitoring team, and amend the damaged road signs, so that every driver at least can follow the road signs that would enable the drivers to know that some areas are dangerous to park. Similarly,, I have observed that while off-loading those pipes at the site, some get cracked at the tips which may be due to the usage of the cranes (*Line 18: faulty machine handling*) (**A3**).

Site Engineer

I have worked with the company about 2 years now as a site engineer. The major factors that cause some activities to be repeated are:

Change of site nature: The nature of the site in which the project is being carried out is subject to change in soil texture (i.e. hard, soft, soil water-level etc) that causes modification of the original procedure of work (*Line 5: changes in work process*) (**B5**).

Lack of experience: Some of the employees have been observed to lack experience (*Line 6: in adequate job experience*) (**A4**) in some aspect of the project area, thus the inadequate overseeing of all site activities has caused that work to be repeated (*Line 8: inadequate supervision*) (**A2**).

Subcontractor work deficiency: It has been observed that the work of the subcontractor has not been meeting the required standard which tends to affect our activities (*Line 10: subcontractors faulty work procedure*) (**B5**) and thus, they need close monitoring of their activities. Areas involving provision of adequate resources such as water tankers and laborers have not been sufficient (*Line 12: inadequate resources*) (**A5**), and has resulted in some of the accidents our drivers experience on the road during transportation of pipes.

Delay in approval: Sometimes the delays we experience relates to the modifications on work while the work is in progress and this usually brings about the revisit of some completed activities after the approval is issued (*Line 17: work delay procedure*) (**B1**). There is slow receiving of responses due to poor implementation of information technology system (IT) (*Line 18: poor IT system*) (**C1**).

Quality Control Engineer

I started with the company barely two years ago, and my duties are to make sure all the work is done according to the specification and approved technical drawing. My report is directed to the company top management and a copy is usually sent to the project manager. During my work, I recognized that the company had some problem to fit with the technical specification due to some quality defects. The main areas of defects are:

Haul Road: Materials used are oversize and lack of water fill for compaction (*Line 6: Oversize materials*) (**F1**).

Excavation: Over excavation and differences experienced in gravel back fill.

Pipe Installation: Pipe damage during handling or during fixing with pushing machine (*Line 8: difficulties of machine*) (**E1**).

Technical drawing: Error in some technical drawing that results in rework of already completed work (*Line 9: defective drawing*) (**$B1_1$**).

Work procedure: Some of the work procedures are not duly followed such as safety (*Line 10: poor safety implementation*) (**B4**).

The company should have more experienced employees (Line 11: lack of experienced worker) (**A4**) and give those good training to be able to operate the machines and equipment (*Line 12: poor training*) (**B2**).

Site Manager

I have worked with the company for more than 15 years now and I have been on this project for two and half years. We tried with my project team to work hard to complete the project on time within expected cost and quality parameters. However, there are some factors that usually occur beyond our control, and lead to errors and omission occurring at the site. Some of which may be borne out of the following:

Employees experience and skills: - The experience of the operators, drivers and technicians is important. Sometimes human resources (HR) send some operators, drivers and technicians to the site and they do not have enough experience to do the job (*Line 8: lack of job experience*) (**A4**).

Lack of training: - The Company has special cranes, transport trucks and punching machines which are advanced but the company does not give good training (*Line 10: lack of training*) (**B2**) for the operators to be able to use those machines in the right way.

Long working hours: - As a result of shortage of the staff, sometimes the company push the employees to work more hours (*Line 13: long working hours*) (**B3**) which make them very tired and thus, subject to stress and fatigue.

Communication problem: - In our project, we have more than 13 nationalities and they all communicate in English. Some mistakes or errors do happen as a result of misunderstanding among them (*Line 17: language barrier*) (**D1**).

Trailers defects: - Some of the trucks that were delivered for the transporting of pipes, sometimes are not suitable for the work (*Line 19: machine not working satisfactorily*) (**$E2_1$**), they might either have design problem or malfunction.

Change in site condition: - the condition of the site sometimes changes from soft to hard water level close to the surface, thereby causing some modification for the approved work procedure (*Line 22: change in work procedure*) (**B5**) and time required to modify.

Inadequate safety procedure: - There is no detailed safety procedure for pipe handling and pipe transportation which has resulted in many accidents or damage occurring at the site (*Line 24: inadequate safety procedure*) (**B4**).

Delay:- The procedure for handling the site documents takes longer than expected before it gets approved by the technical department at the head office, while at the same time we experience a long procedure with the site management level for approval to be granted. I believe steps need to be taken to facilitate this process, as some of those delays were not caused as a result of management taken decision but due to poor implementation of information technology (IT) system (*Line 30: Inadequate IT implementation*) (**C1**).

Inadequate supervision:- Some of the factors that bring about rework are caused as a result of lack of proper supervision and as such there is need to increase the number of supervisors at the site for this project so that we can reduce the number of activities we had to carry out again (*Line 33: Inadequate supervision*) (**A2**). It is also important to note that these supervisors need proper training to be able to handle the operations at site because there are some technicalities involved in the project expected of a supervisor to be aware of (*Line 36: training*) (**B2**).

Project Manager

I have been with the company for some time now. I started working with this pipeline project from its time of commencement, and according to schedule and cost, the project is lagging behind due to some defects we encounter at work. There are several causes of these defects or rework which are:

Labor error: - labor error arises from lack of experience and skills (*Line 5: lack of experience*) (**A4**), communication problem with each other (i.e. labor comes from different regions and have difficulties in the language barrier) (*Line 8: language barrier*) (**D1**). Also, long working hours has been a complaint by the workers (*Line 9: long work hours*) (**B3**), while lack of regular trainings to use some advanced equipment and machines has been a major problem that causes defects (*Line 10: poor training*) (**B2**).

Materials problem: - We had problems with subcontractor query concerning the oversize material (*Line 12: oversize materials*) (**F1**) which are used during the haul road. This usually occurs as a result of poor sieving equipment being used by the subcontractor (*Line 13: poor sieve equipment*) (**E4**), more so, the subcontractor lacks quality control on usage of material at project site (*Line 14: poor quality control*) (**B6**). Furthermore, there is quite a large number of the subcontractors water trucks that are not working properly, and as such, there has not been enough water to make adequate soil compaction which will reduce the dust experience during pipe transportation (*Line 16: shortage of water trucks*) (**$A5_2$**).

Long time taken for approval: - There has been problem experienced in the approval of modifications in the work procedure and/or getting approval on defects related matter from the affected department from the head office. The information technology system has been very poor (*Line 19: poor IT system*) (**C1**).

Pipe damage: - Certain factors bring about pipe damage and mainly result from truck accident due to high speed and/or unclear visibility caused by dust from the haul road (*Line 21: high speed*) (**B4**). Other causes of pipe damage result from poor experience of the operators to use advanced cranes and the pushing machine, thus, defects are bound to result (*Line 23: poor experience*) (**A4**).

Insufficient supervision: - The project being a huge project demands sufficient supervision to ensure that all workers do the work according to the project requirement. Inexperience on the part of some laborers accounts for defects which require sufficient supervision for the activities taken place on project site (*Line 26: Insufficient supervision*) (**A2**).

In short, the impact on the project cost result from the cumulative of these factors which have been mentioned. Likewise, the impact has been felt by the project team and this causes stress and fatigue to the workers (*Line 29: stress and fatigue*) (**A6**), ultimately, this will lead to a reduction of the company's profit and reputation.

Subcontractor Engineer

I have been working with the subcontractor company as a haul road supervisor for some years now. A major problem that I used to experience is the issue of oversized materials (*Line 3: supply of oversized materials*) (**F1**) and inadequate water for soil compaction. The over sized materials result from the poor quality of sieve been used at the quarry (*Line 4: poor sieve equipment*) (**E4**), while the shortage of water for proper compaction was usually as a result of not enough water tankers transporting water to the point of use at the site (*Line 6: Inadequate resources*) (**A5**) but the work needed to go ahead as planned.

Table 13: Shows the numbers of participants and their position

Participant's Position	Frequency
Project Manager	1
Site Manager	1
Site Engineer	3
Quality Engineer	2
Foreman	3
Technician	2
Crane Operator	2
General Labor	4
Drivers (Trailer)	3
Subcontractor Engineer	2
Total	**23**

Table 14: Shows the 1st and 2nd Tie Categories with their Symbols

Themes (2nd Tie)	Codes (1st Tie)	Sub-codes	S_C	S_{Sc}
People	Erroneous workmanship		A1	
	Insufficient supervision		A2	
	Poor machine handling		A3	
	Inadequate work experience		A4	
	Inadequate resources	Laborers	A5	$A5_1$
		Water tankers		$A5_2$
	Stress and fatigue		A6	
Process	Faulty work preparation	Defective drawing	B1	$B1_1$
	Poor training		B2	
	Working long hours		B3	
	Poor safety procedures	Over speeding	B4	$B4_1$

	Change in work process Poor quality control	Damaged safety signs	B5 B6	$B4_2$
Technology	Inadequate use of IT Advanced machines	Slow modification approval	C1 C2	$C1_1$
Communication	Language difficulties		D1	
Machine/Equipment	Machines complications Faulty machines Machines delivered with defects Bad sieve equipment	Machine not working satisfactorily Malfunctioning machines	E1 E2 E3 E4	$E2_1$ $E3_1$
Materials	Oversized materials		F1	

S_C and S_{SC} represent Symbol codes and Symbol sub codes respectively

4.2.3 Financial Data

The project is based on the construction of a water supply system in Libya, herein in this report referred to as pipeline project. The project cut across a large region across the entire country with the aim of providing potable water to the people of the country. As such, it is a huge project which has been valued at a total sum of 980,000,000 USD as the project value. The significant reason in carrying out this research is to study the root cause(s) of rework in pipeline construction project and in particular to determine the financial impact of rework on such a huge pipeline project of this nature. Thus, the researcher has made effort to collaborate with top financial departmental heads to obtain the present financial update on the project based on the progress of the identified categories of the main project structure as explained in a previous section. The project has been categorized into six main sections which are mentioned below:

- Haul Road
- Excavation
- Pipe Transportation
- Pipe Installation
- Back filling
- Concrete work (Manholes)

The project progress has reached 76% of its estimated planned duration and a series of complaints has been received by the main contractor from their client, which are documented in form of non-conformance reports (NCR) which has been explained in a previous section. This section, however, deals with the record of spending and it is out to determine the impact of rework on the total project cost. Table 15 shows the budgeted value for each of the categories and the allocated amounts to be spent with respect to the project has been calculated. An illustration of the apportioned percentage and project values for the budget is described in Figure 8 and Figure 9 respectively.

Table 15: Project Categories with the Project Values

Project Area	Category	Percentage (%)	Budget ($)
	Overhead	8	78,400,000
Haul Road	Haul Road	15	135,2400,000
	Maintenance	4	36,064,000
Pipeline Work	Excavation	35	315,560,000
	Pipe Transportation	7	63,112,000
	Pipe Installation	15	135,240,000
	Back fill	10	90,160,000
	Concrete work	14	126,224,000

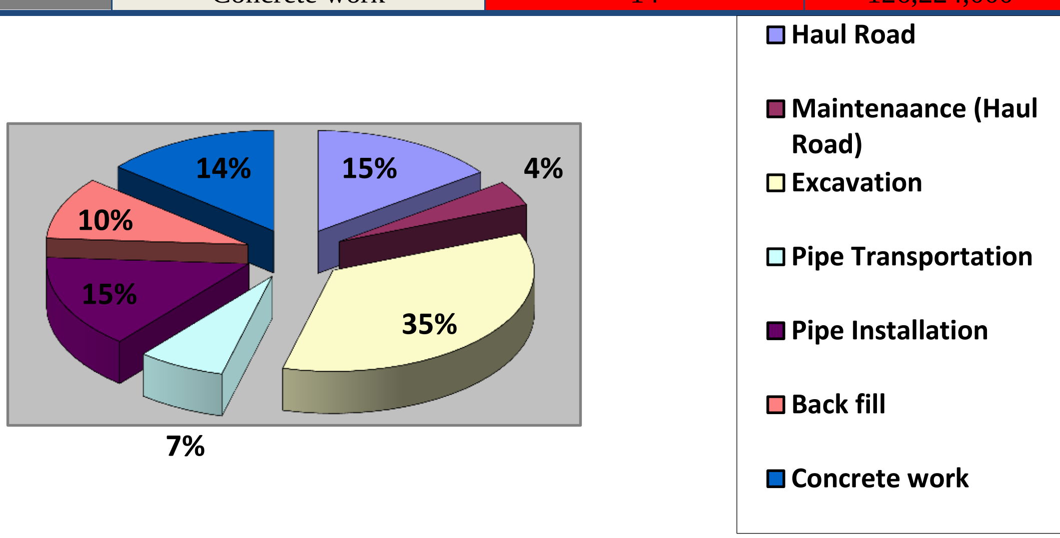

Figure 8: Project Categories with the Project Percentage

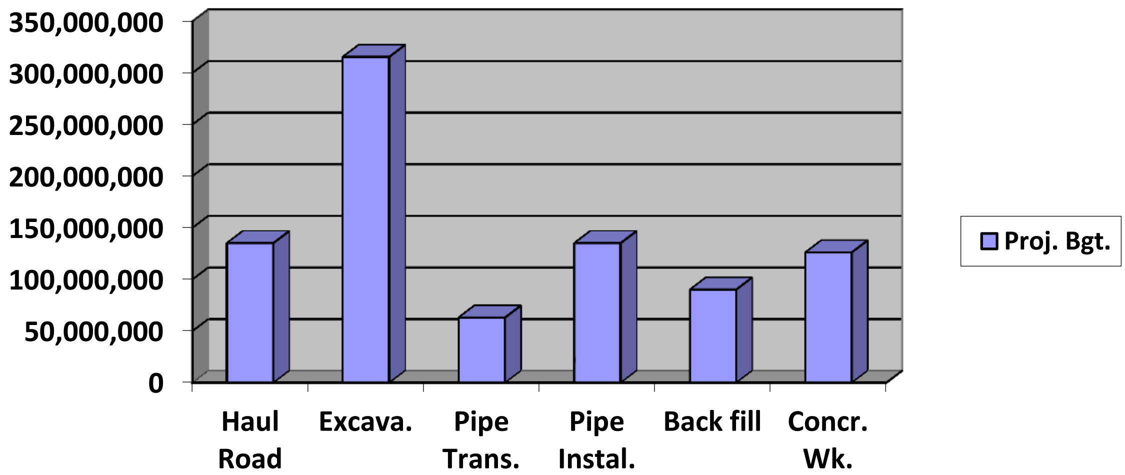

Figure 9: Project Categories with the Project Values

The above table revealed that the bulk of the project budget was allocated to the excavation with 35% and the maintenance of the haul road seems to have the lowest share with 4%. The remainder of other categories falls within 7% - 15%. Pipe transportation and haul road with 15% each, back fill with 14% and the pipe transportation was apportioned 7%. In this research study, apart from obtaining the impact of the rework on the total project cost, it goes further to show the category with the highest observed numbers of rework that took place in the project as the project progressed. Apparently, the excavation has the highest apportioned project budget but percentage of rework shows that the least amount of rework was actually carried out from this project area at 3.67% of rework, while the percentage budgeted for haul road was barely half of excavation, it has the highest percentage of rework at 100% of the project. Table 16 shows details of the project expenditure for each category at their respective project progress. A diagrammatical representation of the rework percentage is shown in Figure 10 and Figure 11 below for clarity.

Table 16: Project progress percentage represented with total project value and percentage of rework (50 samples)

S/N	Category	Planned Cost	Project Progress %	Actual Cost	Rework Cost	% Rework
1	Haul Road	94,668,000	100	101,957,000	7,289,000	7.71%
2	Excavation	172,294,200 220,890,000	78 100	178,617,397	6,323,197	3.67%
3	Pipe Transportation	44,809,520 63,112,000	71 100	46,306,158	1,496,638	3.34%
4	Pipe Installation	90,610,800 135,240,000	67 100	93,465,040	2,854,240	3.15%
5	Back fill	56,800,800 90,160,000	63 100	58,482,104	1,681,304	2.96%
6	Concrete work	76,996,640 126,224,000	61 100	79,206,444	2,209,804	2.87%

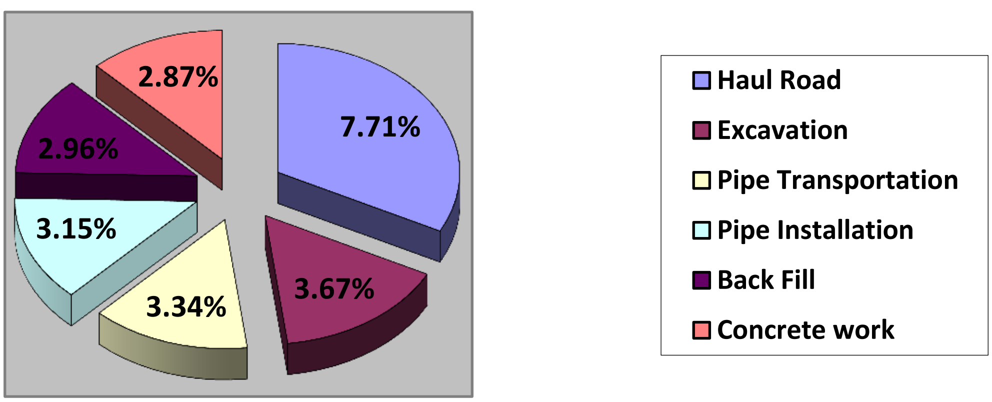

Figure 10: Project Categories with the Percentage of Rework

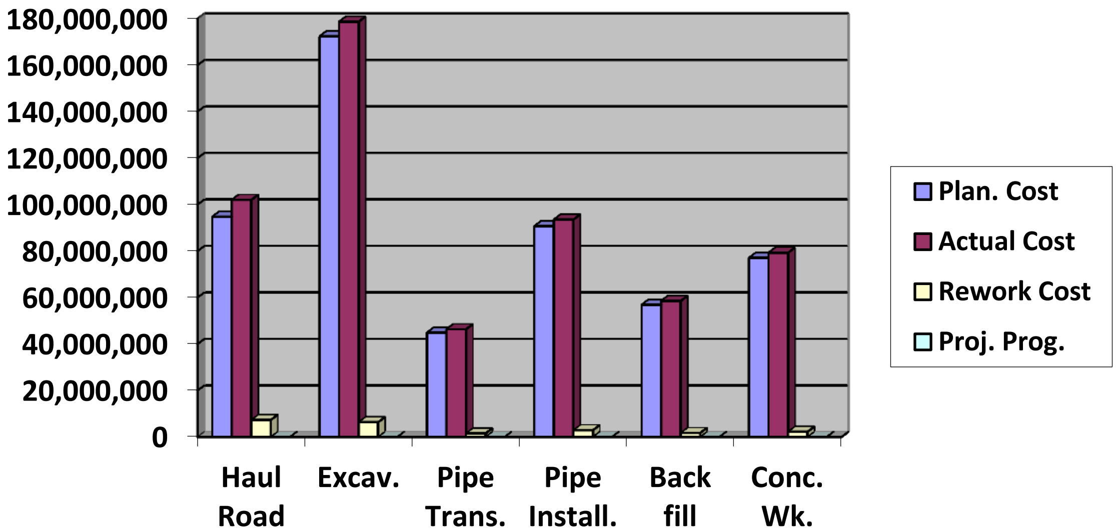

Figure 11: Project Categories Plotted Against Planned and Actual Cost of Project

4.3 Data Analysis

This section presents the analysis of the data collected and explains the relationship gathered from the discussion of the data. It deals with the analysis of the interviews and draws a related conclusion based on the suggestions, experience, and remarks of the interviewees to address the research objectives and invariably verify the developed hypothesis posed in this research study. The analysis of the interviews as described under the research methodology chooses to use coding of the written notes obtained from the interview sessions in relation to various research outcomes on the root cause(s) of rework in pipeline construction project as discussed under the literature review chapter, while further research data helped to determine the impact of rework on total project cost and its performance. Thus, the following sections point in the direction of addressing the research objectives.

4.3.1 Root Cause of Rework

The identification of rework activities in the ongoing pipeline project has been explained under the discussion of data and six project main structures were identified. The interviews conducted with the participants help to discover where the problem lies and draws attention to the root cause(s) of the rework identified in this project. To help in this regard, meaningful segments of the interviewed text were coded, and this process was continued to be applied to all the participants interviewed text. Thereafter, six themes were formed from the coding and explained in the section classification of rework.

Categorizing Rework Cause

As described in the data analysis, six categories were identified as the major project area. These six categories were associated with a series of rework activities, an investigation of these rework activities by the researcher via the interviews conducted with the employees of the main contractor and subcontractor. Each of the project categories were associated with causes obtained from the first level coding of the written documents gotten from the research participant as indicated by the line numbering under the interview section and collated in Table 17.

Haul Road: Most of the rework activities that occurred in haul road construction were associated with poor workmanship, inadequate supervision, supply of oversized materials, inadequate resources (i.e. insufficient water for soil compaction), and poor sieving equipment. These were indicated in the interview section under data discussion with A2, F1, A5, E4, and A1.

Excavation: The activities resulting in rework under excavation were associated with poor workmanship, lack of job experience by the workers, changes in work process, inadequate supervision, working long hours, slow modification approval (IT) and language barriers. These were indicated in the interview section under data discussion with A1, A4, B5, A2, B3, $C1_1$ and D1.

Pipe Transportation: Rework in pipe transportation was associated with inadequate safety procedure, truck malfunctioning, faulty machines and poor condition of the haul road. All these factors were indicated by B4, E3, and E2.

Pipe Installation: Pipe installation activities were observed to have emanated from the difficulty to understand the advanced machines, lack of training, working long hours, inadequate job experience, inadequate supervision, machines not working satisfactorily, and faulty machine handling. These factors have been indicated with E1, B2, B3, A4, A2, and E3.

Back fill: Rework activities experienced during back filling were linked to inadequate resources, inadequate supervision, poor workmanship and working long hours. These can be found with the labels A5, A3, A1 and B3.

Concrete work: Activities associated with concrete work were erroneous workmanship, inadequate supervision, inadequate resources, lack of training, and inadequate job experience. These factors were indicated by A1, A2, A5, B2, and A4 in the interview section under the data discussion.

Formation of Themes

After a significant portion of the interview text had been coded and associated with the activities of project categories, these root causes for the rework were further coded by the formation of themes which are common to the factors developed in the hypothesis. These factors are people, process and technology. Subsequently, the research study found that communication, machines and equipment and materials were also factors that can be generated as themes for this research to qualify as main causes of rework in the ongoing pipeline project. A detail of how these themes contribute to rework is described under the classification of rework.

Table 17: Showing Project Categorization and Root Causes

	Project Categories	Rework Attributes (NCR's data)	Causes
Subcontractor related Rework	Haul road	1. Oversize materials for general filling 2.Soft spots identified on haul roads 3.Borrow pit materials during haul road construction	Lack of supervision Lack of resources Poor workmanship Bad handling of equipment (sieve)
Contractor Related Rework	Excavation	Excavation depth requirement	Poor workmanship Lack of supervision Soil Nature Work procedure Language difficulty

	Pipe Transportation	1.Pipe damage during transportation (Spigot groove). 2.PCCP damage during transportation. 3.PCCP pipe (external & internal mortar cracks) during unloading. 4.Spigot ring damage during unloading.	Poor workmanship Inadequate safety procedures Faulty machines Poor haul road maintenance
	Pipe Installation	1.Pipes need cleaning during installation 2.Spigot damage during the pipe layering 3.Pipe pushing machine got broken 4.Pipe cover depth does not meet specification 5.External mortar crack damage during pipe layering	Difficulty of using machines Poor training Poor workmanship Inadequate supervision Malfunctioning of machines Language difficulty
	Back Filling	1.Back fill soil compactness does not meet requirement (i.e. Structural backfill test). 2.Earth pressure test show that subsurface pipes are prone to damage	Lack of supervision Poor workmanship Inadequate work experience
	Concrete Work (Manholes)	1.Uneven concrete gap in between pipe installation causing faulty Air test 2.Concrete rings test shows that manholes cannot withstand dynamic forces	Lack of supervision Poor workmanship

4.3.2 Classification of Rework

The analysis of the available data for this research study has shown that the rework activities of this pipeline project can be classified into six categories. These categories were deduced from the interview responses of the research participants via the collation of like segment of the written text. Details of the classification are shown in Table 18.

Table 18: Percentage Categorization of Theme Formation

Formation Category (2nd)	Codes	Freq.	First Coding	Rework Percentage
People	A1 A2 A3 A4 A5	2 3 1 2 2	Error workmanship Insufficient supervision Poor machine handling Inadequate work experience Inadequate resources	30%
Process	B1 B2 B3 B4 B5	2 4 2 2 2	Faulty work preparation Poor training Working long hours Poor safety measures Change in work process	35%
Technology	C1	2	Poor IT system	6%
Communication	D1	2	Language difficulties	6%
Machine/Equipment	E1 E2 E3 E4	3 1 2 1	Difficulties of machines Faulty machines Truck malfunction Bad equipment	17%
Materials	F1	1	Oversized of materials	6%

In the above table, the contribution of process to rework as obtained from the causes of the rework is 35% and that associated with people is 30% are the two most important root causes of rework activities in the pipeline construction project. This was followed by the machines and equipment with a value of 17% as their rework percentage, meaning that the contribution of the machines and equipment is not as much as that compared to the project process and the people factors. The other factor shows a minimal contribution to rework activities but nevertheless, still has an impact in the causes of rework in the project. A value of 6% was obtained for technology, communication and materials problems in the rework activities. Figure 12 shows the associated factors to each of the themes identified in the analysis while a graphical representation is illustrated in Figure 13.

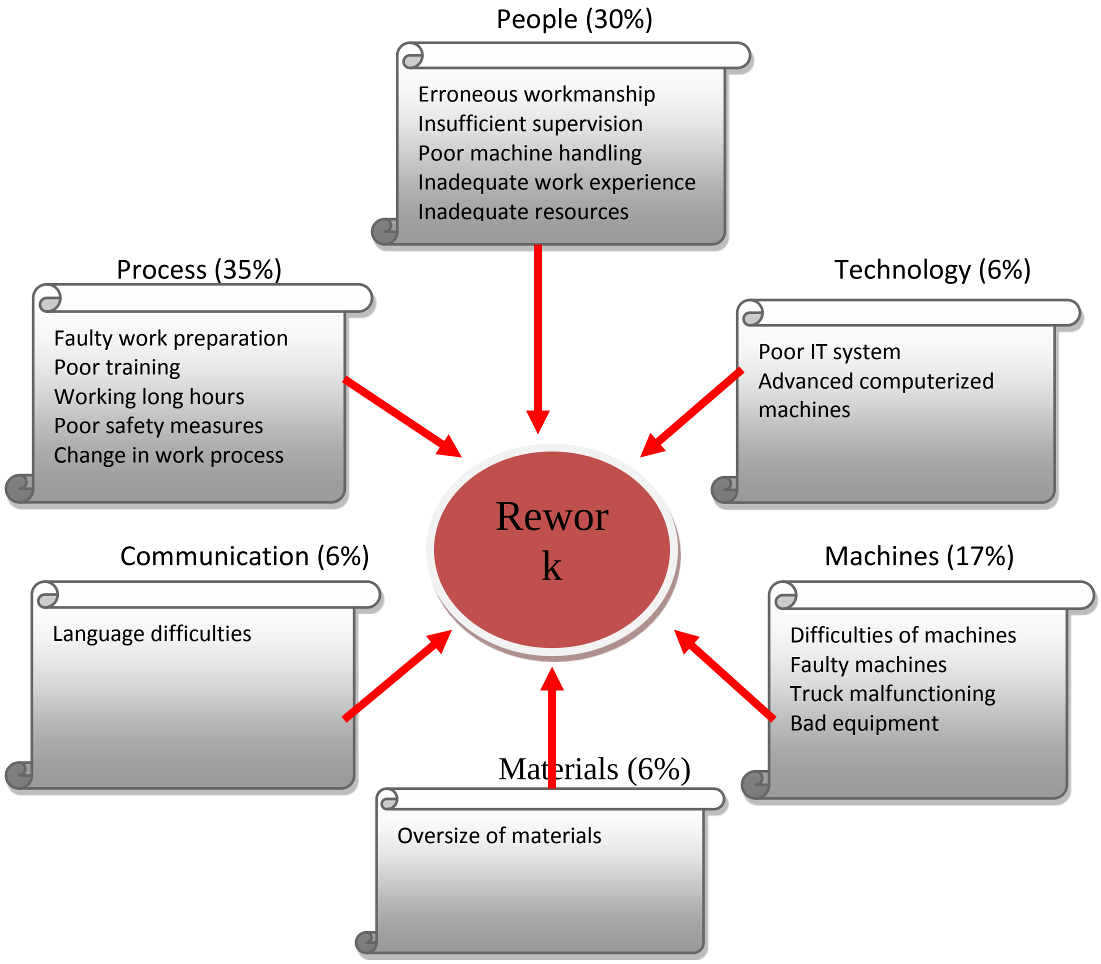

Figure 12: Causes of Rework and their Contributions to Overall Rework Costs

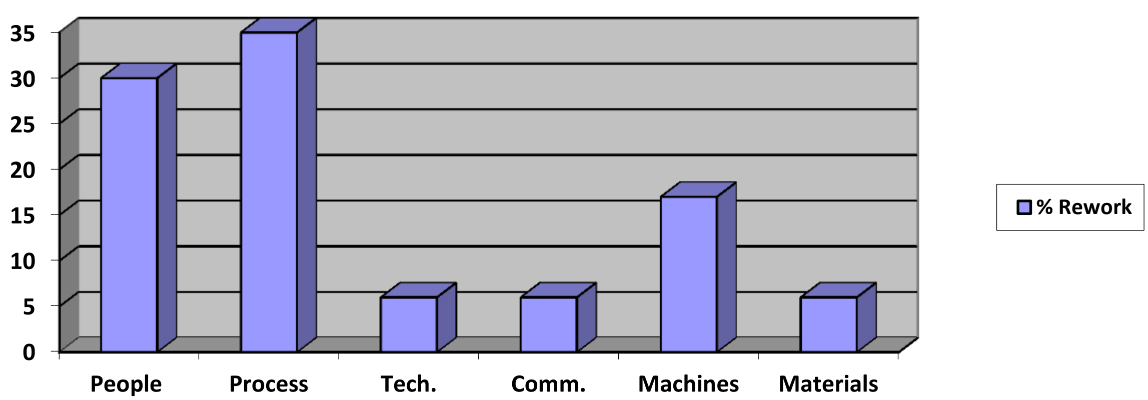

Figure 13: Shows the Project Categories and the Percentage Rework Index

4.3.3 Cost Impact of Rework

The rework impact viewed in this research has been felt across the six project main structures. This section analysis the rework index based on the construction field rework index (CFRI) given in equation 2 in sections 2.

Table 19 below shows the rework index for each of the project main structural areas for the period of the research study.

Table 19: Cost Impact of Project Categories on Rework Index

S/N	Project Area	Total Project Progress Rework Direct Cost (A)	Indirect Cost Markup Value (Field) (B)	Total Rework Cost (C)= (A) x (B)	Total Project Field Progress Cost (D)	Rework Index (E)=(C)/(D)
1	Haul Road	7, 289,000	1.53	11,152,170	101,957,000	10.94%
2	Excavation	6,323,197	1.53	9,674,491.41	178,617,397	5.42%
3	Pipe Transport	1,496,638	1.53	2,289,856.14	46,306,158	4.95%
4	Pipe Installation	2,854,240	1.53	4,366,987.20	93,465,040	4.67%
5	Backfill	1,681,304	1.53	2,572,395.12	58,482104	4.40%
6	Concrete Work	2,209,804	1.53	3,381,000.12	79,206,444	4.27%
Total		21,854,183		33,436,900	558034148	6.00%

The total project progress fields rework cost was deduced from the rework cost of the project for each project category as shown in Table 16 in section which has considered all the total man hours, equipment, materials, and the subcontractors charges were based on.

The resulting value for the indirect cost markup value is the cumulative indirect cost relating to field operations in the ongoing project and it is said to be the multiplication factor. This value was obtained from the division of the contractor's direct and indirect cost value by their total project progress direct cost for the period of the research study (November 2010 – September 2013). In this study, the average of the indirect cost markup value was used as indicated by rework cost in Table 16. This was then used for the calculation of the CFRI calculations, while the indirect cost mark –up value shown in the table was used to multiply the rework cost that has accounted for the total rework cost in column 4 in the above table.

The resulting figure for the project categories indicated that the rework index for haul road was the highest with a value of 10.94% while concrete work comes with the lowest rework index value of 4.27%. Excavation accounts for 5.42% of the rework index in the project, while pipe transportation is with a value of 4.95%, while both pipe installation and backfill had 4.67% and 4.40% of rework index respectively. It was obvious from these values why the concrete work had the lowest CFRI, and this might be why less rework was done in this project category.

Chapter 5.0: Research Results and Discussion

Chapter 5.0 Research Result and Discussion

The focus of this study was centered on investigating, analyzing and discussing the causes and impact of rework on construction pipeline project. After an extensive research finding, the researcher has been able come up with some findings relating to the aforementioned task. A justification of the study was done via a collection of non-conformance report (NCR), one-to-one interviews with key employees working directly on the project, and the collection of the financial data of the project progress. All of this has helped in the result discussed here.

The results are discussed in four sections; firstly, the prevailing factors attached to each project categories of the rework on the pipeline project was described based on its average frequency of occurrence; the second section addresses the causes of the rework, while, impact of the rework on the project performance was delineated in the third section. The cost impact of that rework encountered in the pipeline project on the basis of rework index capped up as the last section.

5.1 Rework Prevailing Factors

The outcome of the study shows that there are six main factors contributing to rework on the construction project. According to the under study pipeline construction project, people, process, technology, communication, materials, and machine and equipment were the prevailing factors contributing to rework. Based on the hypotheses developed in the introductory part of the research, the study supports the first three hypotheses which are stated as follows:

H1: There is a significant relationship between people and the rework in construction projects

H2: There is a significant relationship between the process and the rework in construction projects

H3: There is a significant relationship between technology and the rework in construction projects.

In Table 20, the average frequency of occurrence indicates that the project rework occurs as a result of the consequential causes identified in the study. Furthermore, the study shows that apart from the three prominent factors which are people, process and technology which were revealed in most literature review studies, there are also connections involving communication, materials and machines and equipment in relation to rework in construction projects.

Table 20: Shows the relationship of the main rework causes with the project categories

Category/ Rework Main Factors	Haul Road	Excavation	Pipe Trans.	Pipe Install.	Backfill	Concrete Work	Average Freq.
Main Cause Related							
People	3	2	2	3	3	2	2.50
Process		2	1	1			0.67
Technology		1					0.17
Communication		1		1			0.33
Materials	1						0.17
Machines/Equipment	1		1	1			0.50
Total	5	6	4	6	3	2	

Table 5.0 above indicates the average frequency of occurrence and the total number of the main causes as it affects the project categories. An understanding derived from this table, shows that people and process have the highest impact on rework activities with a value of 2.5 and 0.67 respectively, while machines and equipment follows with a value of 0.5. The study shows a relative low impact of communication, technology and materials to the rework activities, but their presence had significant effects on the rework. Above all, the total number of main factors for excavation, haul road, pipeline installation signifies that a significant number of main causes affects the project categories. For instance, there is a total of 6 main causes each contributing to the rework activities that occurred in both excavation and pipeline installation, while the completed project category on haul road had a total value of 5. It is indicated from the research study that lesser numbers of main rework causes contribute to pipe transportation, backfilling and concrete work. The implication of this rests on the fact that to address the causes of rework in this ongoing pipeline project, these main causes affecting the project categories need to be looked into.

5.2 Causes of the Rework

One of the major objectives of this research study is to identify the cause of rework in the on-going pipeline project. To this effect, six main categories of rework contributing factors have been identified; people, process, technology, communication, materials, and machines and equipment. According to Figure 12, people contributed 30% to the occurrence of rework in the pipeline project. An investigation into this shows that erroneous workmanship, inadequate supervision, poor machines handling, poor work experience of the employees and lack of adequate resources formed the root cause of the problem. Also, the process embarked upon by the management shows that a high percentage of 35% accounts for rework in the on-going pipeline. This is significantly high, and investigation into the problems bringing about this shows that faulty work preparation, poor training, working long hours, inadequate safety measures and the changes in the work process that were not given adequate attention formed the root cause of the problem. Furthermore, machines and equipment had a slightly high percentage compared to people and process with a value of 17%. The root cause associated with machines and equipment are difficulties of the machines, faulty machines, machines delivered with defects, using of defective sieve equipment among others are the root cause of this problem. Although, technology is usually technology associated with rework activities on construction projects but in this study a considerably low value of 6% was obtained, and investigation into the root cause on this pipeline project shows that inadequate implementation of IT system, use of advance computerized systems (i.e. machines) were the key contributing factors to the problem. An average percentage of 6% each was obtained for both communication and materials. The study shows that language barriers and the ability to clearly understand each other was the root cause for communication problem, and the use of oversized materials and formation of good compacted soil were the root cause of material problems that were encountered in this research study.

5.3 Impact of Rework on Project Performance

The impact of rework on construction project can vary from one aspect to the other. It can be in the form of delay (i.e. schedule) to the project, affect the quality of the project, and can impact on the total project cost.

5.3.1 Indirect Impact of Rework

The indirect impact of rework associated with this project was based only on the loss of schedule and productivity. As observed in the literature review, working out indirect rework actually entails lots of things and as such it is difficult to address. Factors that affected the project in this study were the loss of time, poor work protection and improper work sequence that resulted from the workers having to redo the same sets of activities that they had done before. This brings about stress and fatigue to the workers as indicated in the coding of the interviews that was conducted with the workers. Thus, to a reasonable extent this addresses the hypothesis stated below but with a change in phrase as addressed in this research.

H4: The impact of rework has a slight influence on the performance of the project

5.3.2 Cost Impact of Rework

The impact of cost was felt across the entire project categories. The financial data obtained shows that the least amount of rework cost that was experienced as at 71% the project progress on pipe transportation was $1,496,638 and this increases to $7,289,000 which was experienced in the completed part of the project (i.e. haul road). Table 16 shows the project progress percentage represented with total project value and percentage of rework. In this table, the percentage of rework was calculated for each of the project categories. It shows that haul road at 100% project completion had 7.7% of rework, excavation at 78% of the project progress had 3.67%, pipe transportation at 71% of project progress at 3.34%, while pipe installation, backfill and concrete work at 67%, 63% and 61% project progress had 3.15%, 2.96% and 2.87% of rework percentage respectively. On average, it shows that the average percentage of rework for this study is 4.7% based on the average of the project progress. According to previous studies shown in Table 4, the outcome of this study falls within the cost impact of rework calculated in countries like Australia, Singapore, Sweden and UK. However, a quick response to address the causes of the rework identified in this research could reduce the percentage of rework when the pipeline project reaches its completion. It goes to confirm the hypothesis stated below:

H5: The impact of rework has a great influence on the total project cost

Chapter 6.0: Recommendation and Conclusion

Chapter 6.0: Recommendation and Conclusion

6.1 Recommendations

The study examined the causes and effects of rework on an ongoing pipeline construction project in Libya. After an extensive research, it is found out that the causes of rework were predominantly related to: people; process; technology; communication; materials; machines and equipment. Based on the investigation carried out by the researcher, it was found out that quite a large number of factors form the basis of these causes, and if sufficient attention was given, the rework could easily be minimized.

As identified in this study, rework causes like erroneous workmanship, faulty material handling, and faulty machine handling among others, have been associated to human factor (i.e. people). Thus, it is recommended that experienced workforce in terms of labor and supervisor should always be considered. Alternatively, the company should give relevant trainings that would cater for the lower cadre of the supervisors who work directly on the project. This could be done by experienced supervisors to mentor the lower ones so that the lower supervisors could learn from the experience. For instance, an experienced supervisor can ensure the protection of an excavation wall from collapsing; defining the starting point of excavation in a clear and understandable manner, so as to avoid the subsequent usage of large materials, and efficiently manage the resources required. Also, problems associated with the cleaning of pipes bringing about reworking of completed activities could have been avoided if adequate supervision had been in place. It may be obvious that the management of the company has a goal to achieve but the dissemination of the information usually gets lost when there is no one to convey it in the best manner to the executors. Thus, by ensuring the implementation of these recommendations, the high percentage (i.e. 30%) observed in the causes of rework in Figure 12 could be adequately brought to its minimal.

The main cause of rework with a value of 35% has been typically identified as the process under which the project is being executed. There have been problems like faulty work preparation, mistakes in planning, slow procedures on the construction site, poor training, inadequate safety procedures, wrong setting up among others have impacted negatively on the project. It is recommended that the management of such a project employ a suitable work procedure by adopting good planning; implementing a viable information technology (IT) system to facilitate dissemination of change to work activities and giving approvals at the right time. For this, the workforces are given the needed training on IT to facilitate the work procedure, so that the repetition of work would be addressed. Provision of adequate safety measures to reduce or address accident resulting to damages of pipes should also be looked into. The selection of sub-contractors must not be based on the lowest bidder but must be accessed on the grounds of capability and qualification.

The fact that machines and equipment took a value of 17% as the percentage contribution to rework activities in the ongoing pipeline project is significant. It resulted in problems like the difficulty of operating machines, machines delivered with defects, bad sieve equipment, malfunctioning of truck and faulty machines. One of the ways to address this issue is to ensure the proper functionality of those machines at the time of purchase. Moreover, machines used for the project must be reusable without any difficulty. Experienced operators should handle those machines, although a low percentage value (of 6% each) was found as the contributing factor of rework. Language barrier has been a great challenge at the project site which results in misunderstanding among the project team. This leads to repetition of work due to misinterpretation of instructions. For instance, it is recommended that foremen should speak the common language as laborers of different nationalities work on such big projects.

Slow information exchange creates delay resulting in rework. The management should ensure that a systematic IT system is in place which would facilitate documentation, make the assessment of information rapid, and put the internal communication in order.

Lastly, the use of wrong materials not acceptable by clients is another major cause of rework. So, an adequate supervision on the subcontractors work and other facilities of this nature can help to avoid the sub-standard use of materials. Also, the regular inspection of materials supplied to the site by the supervisor should be ensured. This should be done from the point of production (i.e. quarry) before it has been transferred to the project site for its usage.

The findings of the research could be applied to any similar project of the same nature. It can be deduced that adequate attention should be given to the root causes of rework. Contractors should know how to deal with the unforeseen situation resulting in rework. This can be achieved by ensuring the following:

- Project staff should be properly equipped i.e. properly trained or possess previous experience.
- Contractor supervisors should be qualified possessing skills of supervising the required work at the project site.
- The selection of sub-contractor should be based on qualification not on the basis of lowest bidder selection process.
- Before the commencement of work, detailed work descriptions should be given to a sub-contractor and the workers in order to execute the task ahead adequately.
- To minimize errors in drawings, contractors are advised to regularly inspect and ensure that they comply with the required drawings provided by clients.
- Contractors should take proactive steps to solving rework activities in a project, so work should be done in an effective and efficient way.
- To manage the project resource, a contractor should define the required number of people, and clearly estimate machinery required for the project.
- Contractors should ensure an effective IT system is implemented to facilitate information flow, fast approval to enhance the decision making processes.

6.2 Conclusion

For the construction industry, one of the major challenges affecting the industry is rework. In this study, effort was made to investigate the causes and effects of rework. The study revealed that rework is as a result of errors by people, in process, in communication, and in wrong use of materials/machines/equipment. The consequences of these cause impacts on the project performance, and on the total cost of the project. A careful review of the NCR's shows that there is a huge amount of rework that occurs several times, showing that there has not been sufficient close monitoring to avoid rework as experienced on the pipeline project.

Based on the 50 random samples collected for the research purpose, it was found that there are six project categories namely: Haul road; excavation; pipe transportation; pipe installation; backfilling and concrete work. Examining of the NCR's, a ranking order was obtained with haul road topping the rank order with 18 times occurrence, following pipe installation with occurrence of 13, backfill and pipe transportation with occurrence value of 6, and concrete work and excavation having an occurrence value of 4 and 3 respectively. The impact of this rework has been noted in the total cost of project. The findings from this study have brought the following

- The study discovers the rework prevalence in construction projects
- The study finds out the root causes and their categorization to pipeline projects
- The impacts of rework on the total project cost was observed in the pipeline project
- The study tries to find out possible solutions on how to address the problem of rework

It is worthy of note that the root causes of rework in the ongoing pipeline project are factors that are prevalent in most construction projects. The outcomes and recommendations made by the research can be helpful in addressing the problem of rework in similar construction projects. The causes of rework can be subjective factors that may best be addressed by interaction with the people concerned as in this research study it is through interviews. The financial data helps the study to operationalize the 50 samples that are collected at random, thus, it has helped to reveal in particular where most of the rework activities are done. In a nutshell, the findings of this investigation on 'rework' would help to address or reduce the unexpected increase in total project cost and also in finding ways to avoid its occurrence to the minimal.

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APPENDIX I

Study Name	Year Published	Field Rework %	No. of Projects Studied
CII Research Summary 10-1	1989	12% total Design = 9.5% Construction = 2.5%	9 industrial projects
Benchmarking & Metrics Data Report	1997	3.4%	19 industrial projects
Investigation of field Rework In Industrial Construction – CII Research Report 153-11	2011	4.4%	109 industrial projects
Construction Productivity Research Program Phase III	2011	2% - 20%	Unidentified
The Field Rework Index: Early Warning for Field Rework and Cost Growth	2011	4.4%	153 projecrs
Costs of Quality Deviations in Design and Construction	1989	17.5% total Construction Deviations = 2.5%	9 industrial projects
Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry	2004	1% of sf cost/sf	Unknown
Private interview with Executive of global EPC firm	2012	2% - 5%	35 years of experience with same firm
Causes of Quality Deviations in Design and Construction	1992	Design = 9.5% Construction = 2.5% Fabrication = 0.3% Operability = 0.1%	9 projects
The Causes and Costs of Defects in Construction: A study of Seven Building Projects	1999	2% - 6%	7 projects
Quantifying the causes and Costs of Rework in Construction	2000	10% Total Variations = 1.9% Non- Variations = 0.7% Defects = 0.3%	2 projects
Measuring and Classifying Construction Field Rework: A Pilot Study	2003	Direct cost = 0.5% Indirect cost = 0.4% Total cost = 0.9%	1 project
Learning to Reduce Rework in Projects: Analysis of Firm's Organizational Learning and Quality Practices	2003	0% -35%	Unknown
Adding Value to the Facility Acquisition Process: Best Practices for Reviewing Facility Designs	2000	12.4% total Design errors = 9.9%	Unknown

		Construction errors = 2.5%	
Influence of Project Type and Procurement Method on Rework Cost in Building Projects **Respondent Type** Designers Constructors Project Managers Total	2002	12% total Direct Costs = 8.0% Indirect Cost = 6.8% Direct Costs = 5.8% Indirect Costs = 5.5% Direct Costs = 4.3% Indirect Costs = 3.6% Direct Costs = 6.4% Indirect Costs = 5.6%	161 projects