Causes and Effects of Rework: A Study on a Major Water Supply Pipe-Line Construction Project in Libya

Abdel Rahim Al Zanati and Arun Bajracharya

***Abstract*—This study attempts to investigate the causes of rework and how rework affect the cost performance of project. An ongoing major water pipe-line project in Libya was considered for the study. Data were collected mainly from three sources: first, a set of 50 samples of non-conformance report (NCR); second, financial information pertaining to the sample NCRs; and third, semi-structured interviews with key staff at the project site. Interview data were analysed using the theoretical coding approach to determine the causes of rework. Analysis of the collected financial data helped in realising the cost impact of rework. The findings revealed five categories of causes of rework: the people, process, technology/machines/equipment, materials, and communication, among which people and process related causes were dominant. The cost effect of the rework on different work packages in the project ranged from 2.78% to 7.70% resulting into 4.08% increase in the planned cost of the project in average.**

***Index Terms*—Rework, causes of rework, cost effects of rework, water supply pipe-line project, Libya.**

I. Introduction

Rework is generally taken as a set of undesirable ex-post corrective activities that become necessary to be addressed and executed for successive work completion in a project. In the course of project implementation, due to one or the other reason, need for rework start creeping in [1], and often it affects the time schedule, costs, and quality of the project [2]. Some of the scholars report that the incidence of rework is taken as almost inevitable and acceptable as a normal function of operation [3], [4]. It has also been found that costs of rework would be implicitly included in project cost contingency [5]. However, at the same time it cannot be ignored that the costs of rework would be significant as it could range from 3.5% to 25% of contract value in projects [2], [6], [7]. Even though the costs of rework are important to be considered, more important would be the causal explanation of rework [8]-[10] so as to understand how to minimise the occurrence of rework and its adverse effects in the project.

Therefore, this research considers rework as a significant problem in construction projects, and the main causes and effects of rework have been investigated by conducting a detail study with field data collected from an ongoing large-scale water pipe-line project in Libya.

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II. Description of the Water Pipe-Line Project

In this research, a part of a major water supply pipe-line construction project in Libya was taken as a case project for study. Because of the confidentiality issue, the identity of the project will not be revealed, but the general features of the project will be disclosed.

The project was a highly ambitious government project that was launched to transfer the water from southern part of Libya to the northern part. The main purpose was to utilise the huge natural underground water reserves in the south to serve the population, agriculture and industry base in the north. The complex multi-billion dollar project had the estimated pipe-line length of 4000km. The expected conveyance capacity of the project was 6.5 million cubic meters per day. For the conveyance system, pre-stressed concrete pipes were used. Each of the pipe segments was 73 to 80 ton in weight, 7.5 meter long, and 4 meter in diameter. The pipes were to be laid underground by creating 7 meter wide and 7 meter deep trench.

This research considered a part of the pipe-line construction project which was being carried out by a Turkish main contractor. The contractor was responsible in completing a 383km long section of the project with design and build contract. The water supply project was commenced in 2006, but the part of the main contractor’s works started from November 2010 with the total estimated time duration of 48 months. At the time of doing this research, around 76% of the works on the part of the contractor had been completed.

III. Research Methodology

In this research an attempt has been made to investigate and analyse the occurrence, causes and effects of rework by observing the progress of the project, and by analysing the relevant experience and understanding of project staff. Mainly a qualitative research method was used to collect and analyse the data. Firstly, secondary data were collected by observing the site situation, and reviewing the non-conformance and financial reports. The non-conformance reports (NCRs) were a collection of site reports originating from the side of client claiming non-conformance of work done at the site with the signed contract. A total of 50 NCRs were collected and this served as the basis for examining the causes of the rework on the project.

Cost implications of rework were considered as the (cost) effects of rework in this research. So in order to evaluate the effects of rework on the on-going project, relevant financial data were collected. The financial data were distilled to get information about the actual costs of work packages and that of rework on the corresponding work packages. The costs of rework were the incurred costs for completing the additional works successfully as they were mentioned in their respective NCRs.

Primary data were collected by conducting a series of interviews with the staff working for the main contractor. Precisely, the population frame for the study was the operations staff working at the site at the time of research. The sampling of respondents was done on the basis of convenience – that means whoever available and willing for interview was selected as sample respondent. Altogether a total of 23 respondents (as shown in Table I) were interviewed over the span of three week data collection time.

TABLE I: THE SAMPLE RESPONDENTS

Respondents	Number
Project Manager	1
Site Manager	1
Site Engineer	3
Quality Engineer	2
Foreman	3
Technician	2
Crane Operator	2
General Labour	4
Drivers (Trailer)	3
Subcontractor's Engineer	2
Total	23

The interviews were aimed at finding out the causes of rework, and thus it was emphasized that the respondents share their point of views with respect to the causes of the non-conformed works. A set of semi-structured interview questions were used for the purpose. The duration of interview with each of the interviewees was around 40-50 minutes, and the interview data were collected in terms of notes on their responses. The notes were transcribed into texts as soon as each of the interviews was over. All the transcribed data were collected and then analyzed by using the formal method of theoretical coding (see literature such as [11] and [12] for detail on theoretical coding).

IV. IDENTIFICATION OF REWORK

For this study, the instances of occurrence of rework in the project were identified by studying the non-conformance reports (NCR) which used to be produced by client's representative in order to monitor the progress of the project. The NCR signified something that had gone wrong, which was needed to be addressed so as to amend the work as per the contract specification – this essentially was nothing but the indication of required rework in the respective work area. The NCR also used to include the acceptable corrective action needed to address the "non-conformed" work items.

A total of 50 randomly selected NCR samples were collected from the contractor's site manager. By analysing the contents, the sample NCRs with their respective frequency of reporting could be categorised into six different work packages of the project as shown in Table II.

TABLE II: NCRS AND THEIR CORRESPONDING WORK PACKAGES

S. N.	Work Packages	NCR Description
1.	Haul Road	1a. Oversized materials were used in the filling work in the haul road construction (7)* 1b. Soft spots were identified on the haul road (6) 1c. Inferior borrow pit materials were used during the haul road construction (5)
2.	Pipeline Installation	2a. Pipes needed special cleaning during installation (2) 2b. Spigot damage found during the process of pipe laying (3) 2c. Pipe placement machine got broken during operation that resulted cracks in the pipe (3) 2d. Pipe cover depth did not meet specification (2) 2e. External mortar cracked during the process of pipe laying (3)
3.	Backfilling	3a. Failure in the structural backfill test (backfill soil compactness did not meet the requirement) (3) 3b. Failure in the earth pressure test (the subsurface pipes were prone to get damaged in the test pressure) (3)
4.	Pipe Transportation	4a. Pipe damage during transportation (Spigot groove) (2) 4b. PCCP damage during transportation (1) 4c. PCCP pipe (external & internal mortar cracks) during unloading (1) 4d. Spigot ring damage during unloading (2)
5.	Concrete Works	5a. Uneven concrete gap in between pipe installation causing failure in the air test (3) 5b. Concrete rings in the manholes failed the test with dynamic forces (1)
6.	Excavation in the Trench of Pipeline	6a. Depth of excavation did not meet the requirements (3)

** Numbers in parenthesis indicate the frequency of the work observed in the NCR samples*

The six categories of work packages presented in Table II have been presented in a rank order with the Haul Road being the first and the Excavation in the Trench being the sixth in terms of frequency of the respective NCRs. In the sample of 50 NCRs, there were 18 on Haul Road, 13 on Pipe Installation, 6 on Backfilling, 6 on Pipe Transportation, 4 on Concrete Works, and 3 on the Excavation in the Trench related works.

V. DATA ANALYSIS AND DISCUSSION

Summary of the interview data analysis output have been presented from Table III to VIII. The NCR or rework description, first tier causes and then categories (themes) of the causes have been presented for each of the six work packages separately. The first tier causes were categorised into five distinct themes namely People, Process, Machine/Equipment/Technology, Materials, and

Communication. The categorisation of the themes was done by segregating the stated causes into in thematically independent domains. In the Tables, the figures in parenthesis (except the % figures) are the frequency of observation of the respective package, description or cause.

TABLE III: WORK PACKAGE: HAUL ROAD (18)

NCR Description 1a. Oversized materials were used in the filling work in the haul road construction (*7*) 1b. Soft spots were identified on the haul road (*6*) 1c. Inferior borrow pit materials were used during the haul road construction (*5*)
First Tier Causes • Inferior sieving equipment used by sub-contractor (*2*) • Inadequate water for compaction (*3*) • Inadequate number of water tankers at the site (*1*) • Poor quality control in the usage of materials at project site (*1*) • Faulty work procedure (*1*) • Water tankers not working properly (*1*) • Inadequate supervision (*3*) • Communication problems due to diversity in workforce (*2*) • Lack of supervisor training (*1*)
Categories of Causes *People (26.67%)* • Inadequate supervision (*3*) • Lack of supervisor training (*1*) *Process (13.33%)* • Poor quality control in the usage of materials at project site (*1*) • Faulty work procedure (*1*) *Machine/Equipment/Technology (26.67%)* • Inferior sieving equipment used by sub-contractor (*2*) • Inadequate number of water tankers at the site (*1*) • Water tankers not working properly (*1*) *Materials (20%)* • Inadequate amount of water for compaction (*3*) *Communication (13.33%)* • Communication problems due to diversity in workforce (*2*)

TABLE IV: PIPE INSTALLATION (13)

NCR Description 2a. Pipes needed special cleaning during installation (*2*) 2b. Spigot damage found during the process of pipe laying (*3*) 2c. Pipe placement machine got broken during operation that resulted cracks in the pipe (*3*) 2d. Pipe cover depth did not meet specification (*2*) 2e. External mortar cracked during the process of pipe laying (*3*)
First Tier Causes • Operators lacking knowledge and skills to use heavy installation equipment (*1*) • No specific training given in using installation equipment (*2*) • Learning by doing the installation work (*1*) • Lack of preparation in the work with installation and other advanced equipment (*1*) • Lack of specialist support in finishing the fixing work (*1*) • Communication problems due to diversity in workforce (*3*) • Difficulties to use advanced functions of the crane (*1*) • Lack of training in using the crane and advanced equipment (*3*) • Terminate the appointment of crane operator in the event of mistake and recruit an entirely new operator instead of training the former (*1*) • Faulty use of pushing machine in pipe laying (*1*) • Inadequate safety procedures in pipe handling (*1*) • Lack of experience in handling cranes and pushing machines (*2*) • Lack of skills and job experience of labourers (*5*) • Inadequate supervision (*3*) • Errors in technical drawings (*1*) • Work procedures such as safety procedures were not duly followed (*1*) • Fatigue due to long working hours (*3*) • Lack of supervisor training (*1*)
Categories of Causes *People (68.75%)* • Operators lacking knowledge and skills to use heavy installation equipment (*1*) • No specific training given in using installation equipment (*2*) • Learning by doing the installation work (*1*) • Lack of training in using the crane and advanced equipment (*3*) • Terminate the appointment of crane operator in the event of mistake and recruit an entirely new operator instead of training the former (*1*) • Lack of experience in handling cranes and pushing machines (*2*) • Lack of skills and job experience of labourers (*5*) • Inadequate supervision (*3*) • Fatigue due to long working hours (*3*) • Lack of supervisor training (*1*) *Process (15.63%)* • Lack of preparation in the work with installation and other advanced equipment (*1*) • Lack of specialist support in finishing the fixing work (*1*) • Inadequate safety procedures in pipe handling (*1*) • Errors in technical drawings (*1*) • Work procedures such as safety procedures were not duly followed (*1*) *Machine/Equipment/Technology (6.25%)* • Difficulties to use advanced functions of the crane (*1*) • Faulty use of pushing machine in pipe laying (*1*) *Materials (0%)* • None *Communication (9.38%)* • Communication problems due to diversity in workforce (*3*)

TABLE V: BACKFILLING (6)

NCR Description 3a. Failure in the structural backfill test – backfill soil compactness did not meet the requirement (*3*) 3b. Failure in the earth pressure test – the subsurface pipes were prone to get damaged in the test pressure (*3*)
First Tier Causes • Discrepancy in the trench depth specifications and the actual site requirements (*1*)

- Effects on the works of labourers due to fatigue (*1*)
- Lack of labourer (*1*)
- Changes due to variation in the underground soil and water table conditions (*1*)
- Variation in particle size of the soil used in backfilling (*1*)
- Lack of skills and job experience of labourers (*5*)
- Inadequate supervision (*4*)
- Errors in technical drawings (*1*)
- Lack of training of workers (*1*)
- Fatigue due to long working hours (*3*)
- Communication problems due to diversity in workforce (*2*)
- Lack of supervisor training (*1*)

Categories of Causes

People (72.73%)
- Effects on the works of labourers due to fatigue (*1*)
- Lack of labourer (*1*)
- Lack of skills and job experience of labourers (*5*)
- Inadequate supervision (*4*)
- Lack of training of workers (*1*)
- Fatigue due to long working hours (*3*)
- Lack of supervisor training (*1*)

Process (13.64%)
- Discrepancy in the trench depth specifications and the actual site requirements (*1*)
- Changes due to variation in the underground soil and water table conditions (*1*)
- Errors in technical drawings (*1*)

Machine/Equipment/Technology (0%)
- None

Materials (4.55%)
- Variation in particle size of the soil used in backfilling (*1*)

Communication (9.09%)
- Communication problems due to diversity in workforce (*2*)

TABLE VI: PIPE TRANSPORTATION (6)

NCR Description

4a. Pipe damage during transportation – Spigot groove (*2*)

4b. PCCP damage during transportation (*1*)

4c. PCCP pipe (external & internal mortar cracks) during unloading (*1*)

4d. Spigot ring damage during unloading (*2*)

First Tier Causes

- Accidents due to poorly maintained haul road conditions and reckless high speed driving (*2*)
- Trailers not in good condition (*1*)
- Faulty usage of cranes in the off-loading process (*1*)
- Lack of training in operating sophisticated transport trucks (*3*)
- Trucks were not suitable for the intended works, and they were not working satisfactorily due to lack of repair and maintenance (*1*)
- Inadequate safety procedures in pipe transportation (*1*)
- Lack of supervisor training (*1*)
- Lack of skills and job experience of labourers and drivers (*5*)
- Inadequate supervision (*3*)
- Fatigue due to long working hours
- Communication problems due to diversity in workforce (*2*)

Categories of Causes

People (65.23%)
- Lack of training in operating sophisticated transport trucks (*3*)
- Lack of skills and job experience of labourers and drivers (*5*)
- Inadequate supervision (*3*)
- Fatigue due to long working hours (*3*)
- Lack of supervisor training (*1*)

Process (17.39%)
- Accidents due to poorly maintained haul road conditions and reckless high speed driving (*2*)
- Faulty usage of cranes in the off-loading process (*1*)
- Inadequate safety procedures in pipe transportation (*1*)

Machine/Equipment/Technology (8.70%)
- Truck-trailers not in good condition (*1*)
- Truck-trailers were not suitable for the intended works, and they were not working satisfactorily due to lack of repair and maintenance (*1*)

Materials (0%)
- None

Communication (8.70%)
- Communication problems due to diversity in workforce (*2*)

TABLE VII: CONCRETE WORKS (4)

NCR Description

5a. Uneven concrete gap in between pipe installation causing failure in the air test (*3*)

5b. Concrete rings in the manholes failed the test with dynamic forces (*1*)

First Tier Causes

- Lack of skills and job experience of labourers and technicians (*5*)
- Communication problems due to diversity in workforce (*2*)
- Inadequate supervision (*3*)
- Lack of training of workers (*1*)
- Lack of supervisor training (*1*)
- Errors in technical drawings (*1*)
- Fatigue due to long working hours (*3*)

Categories of Causes

People (81%)
- Lack of skills and job experience of labourers and technicians (*5*)
- Inadequate supervision (*3*)
- Lack of training of workers (*1*)
- Fatigue due to long working hours (*3*)
- Lack of supervisor training (*1*)

Process (6%)
- Errors in technical drawings (*1*)

Machine/Equipment/Technology (0%)
- None

Materials (0%)
- None

Communication (13%)
- Communication problems due to diversity in workforce (*2*)

TABLE VIII: EXCAVATION IN THE TRENCH OF PIPELINE (3)

NCR Description 6a. Depth of excavation did not meet the requirements (*3*)
First Tier Causes • Discrepancy in the trench depth specifications and the actual site requirements (*1*) • Effects on the works of labourers due to fatigue (*4*) • Insufficient labour and supervisor resources (*1*) • Changes due to variation in the underground soil and water table conditions (*2*) • Excessive excavation (*1*) • Lack of skills and job experience of labourers (*5*) • Inadequate supervision (*3*) • Errors in technical drawings (*1*) • Lack of training of workers (*1*) • Communication problems due to diversity in workforce (*2*) • Lack of supervisor training (*1*)
Categories of Causes *People (68%)* • Fatigue due to long working hours (*4*) • Insufficient labour and supervisor resources (*1*) • Lack of skills and job experience of labourers (*5*) • Inadequate supervision (*3*) • Lack of training of workers (*1*) • Lack of supervisor training (*1*) *Process (23%)* • Discrepancy in the trench depth specifications and the actual site requirements (*1*) • Changes due to variation in the underground soil and water table conditions (*2*) • Excessive excavation (*1*) • Errors in technical drawings (*1*) *Machine/Equipment/Technology (0%)* • None *Materials (0%)* • None *Communication (9%)* • Communication problems due to diversity in workforce (*2*)

Observing the frequency of the causes (that is the number of times interviewees mentioned the similar cause for the respective rework), it can be seen that in all the work packages the most frequently mentioned causes of rework were people related causes. Lack of skills and job experience of labourers and workers seemed to be the most critical people related cause. Fatigue due to long working hours was found to be the second most critical people related cause. Inadequate supervision and lack of training for labourers and supervisors were the third most critical people related causes.

Process related causes were the second most frequently mentioned category of the causes in all the work packages except the haul road. There were diverse process related causes in the respective work packages, but among them accidents due to poorly maintained haul road conditions and reckless high speed driving, and changes due to variation in the underground soil and water table conditions were the most frequently mentioned causes of the rework in pipe transportation and trench excavation packages.

Communication was the third most frequently mentioned category of the causes in all the work packages except the haul road. Diversity in workforce was mentioned as the main cause behind the communication problems that led to a number of rework in all the work packages. Another category of causes was machine/equipment/technology which is the most frequently mentioned category in haul road package and it is fourth most frequently mentioned one in pipe installation and pipe transportation packages. Inferior, inadequate, non-functional, difficult to use, faulty use of, and unsuitable machine/equipment/technology were the mentioned causes.

The materials as the category of causes was least frequently mentioned in all the packages except in haul road. Inadequate amount of water for compaction, which is under the materials category, is one of the second most frequently mentioned causes in haul road. Variation in particle size of the soil used in backfilling is another material related cause that was mentioned once in backfilling work package.

TABLE IX: SUMMARY OF THE COST EFFECTS (IN M US$)

S. N.	Work Packages	Actual Cost	Rework Cost	Rework Cost*
1.	Haul Road (Planned Cost at 100% completion: 94.67)	101.96	7.29	7.70
2.	Pipeline Installation (Planned Cost at 67% completion: 90.61)	93.47	2.85	3.15
3.	Backfilling (Planned Cost at 63% completion: 56.80)	58.48	1.68	2.96
4.	Pipe Transportation (Planned Cost at 71% completion: 44.81)	46.31	1.50	3.34
5.	Concrete Works (Planned Cost at 61% completion: 77)	79.21	2.21	2.87
6.	Excavation in the Trench of the Pipeline (Planned Cost at 78% completion: 172.29)	178.62	6.32	3.67

** In terms of % of the planned costs*

Table IX presents a summary of the cost effects of rework in the six work packages. The total cost of satisfactorily completing the works mentioned in NCRs have been taken as the cost effects of rework. At the time of data collection, only haul road was 100% complete and rest of the packages were in the range of 61% to 78% completion. It was found 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 had 3.34%, while pipe installation, backfilling and concrete works at 67%, 63% and 61% project progress had 3.15%, 2.96% and 2.87% of rework percentage respectively. It shows that the average percentage of rework was 4.7% based on the average of the project progress. In terms of the absolute cost figures, the rework costs ranged from US$ 1.496m (pipe transportation, 71% complete) to US$ 7.289m (haul road, 100% complete), and the total rework cost amount was US$ 21.854m at the stage of 76% overall completion.

VI. Conclusion

This research investigated the causes and effects of rework in a construction project in a developing country. Data from a major water pipe-line project in Libya were collected and used for analysis. The interpretive interview data analysis revealed five categories of causes of rework in six different work packages in the project. Among the five categories, people and process related causes were most frequently mentioned causes of the rework.

Analysis on the financial data revealed that the cost effects of rework ranged from 2.87% to 7.70% increase in the planned costs of the work packages resulting into an average of 4.08% increase in the total cost of the project package at the completion point of 76% of the estimated duration.

The findings of this research mainly indicate that the lack of attention and investment especially in selection, allocation, training and incentivising people could lead to significant amount of loss in terms of costs of rework in the project. The people related factors which are the major ones, and the process related factors which are mostly the derivatives of the people related factors seem to be generally overlooked by the management of the project probably because their consequential effects had not been foreseen in the context of other priorities and pressure during project execution.

This research is based on one single case study on a part of a big project, and as such the findings might not be readily generalisable in a wider context. However, the findings of the research carried out in a remote part of a typical developing country in North Africa are expected to be useful at least for other similar projects in and around the region.

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