

# COST IMPLICATIONS OF REWORK DUE TO DESIGN ERRORS IN INSTITUTIONAL BUILDING PROJECTS IN ABUJA

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The impact of rework on construction project performance has become a major source of concern to construction professionals and clients of the construction industry. One of the root causes of rework is design error, as the phrase implies, it is any deviation from original design which could also mean any omission and ambiguity. Design errors occur more in the construction of frame structures because of the complications involved in their designs. The aim of this research is to determine the cost implication of rework due to design error, the relationship between cost of rework due design error and the initial contract sum and final contract sum of institutional building projects in Abuja. Institutional building projects are basically framed structures; hence the research is focused on such projects. Quantitative method of research was employed where archival data were sourced from completed institutional building projects files. The data were sorted and analysed using correlation analytical tool. The result of the analysis revealed that a positive correlation exists between rework cost and final contract sums. Secondly the initial and final contract sums were found to be significantly affected by rework. The study concluded that rework occurrence due to design error(s) automatically results to a significant increase in the contract sum which could lead to other issues such as delay in project completion and in extreme cases project abandonment. The study recommends the introduction of multidisciplinary design team during the design stage and ample time for all involved so as to reduce the rate of errors, omission and ambiguity. Clients should be advised on the cost implications of frequent changes which usually leads to rework so as to get detailed client brief during the design stage before construction commences.

**Keywords:** *Design errors, Institutional buildings, Project cost, Rework.*

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## INTRODUCTION

Design errors are problematic in construction and engineering projects. They have been recognised to have created an unsafe and unpleasant environment which can result in casualties (Love *et al.*, 2010). Design error is a deviation from a drawing or specification, also including omission and ambiguities. Professionals in the built environment and civil engineering still find it difficult particularly with identifying and preventing design errors (Lopez *et al.*, 2010). Design errors continued to be a major factor to building failures, time and cost overruns (Sun and Meng, 2009). Generally, it is during the execution and implementation stages of projects that design errors are noticed and identified which usually leads to rework (Oyewobi *et al.*, 2011). The extent of this error is what must be looked into in order to determine the consequence on the overall project cost.

Rework has become a frequent happening in construction projects and has been identified as one of the factors that can reduce the quality of project performance. “the construction industry institute (CII, 2001) defines rework as an activity that has been done more than once or activities that remove work previously installed as part of a project”. Under the pressure to improve project cost and schedule performance many companies have embraced the speed up approach in which the design phase and the construction phase overlap (Pena-mora and Li, 2001).

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Due to this phase overlap the contractor can start the construction phase with flawed or defect plans that have undiscovered errors. This undiscovered rework in the design stage can bring about a major amount of rework in the construction phase. The architects play a very vital role because any deficiency or errors in the inception phase may lead to successive deviation in the construction phase (Oyedele and Tham, 2007).

Love *et al* (2009), argued that the longer an error stays undiscovered and undetected the more the possibility of rework occurring which significantly affects cost and schedules. According to (Love *et al*, 2009) there are a number of silent condition within a project that that causes error provoking activities to take place and therefore contributes to rework occurrence downstream during construction. Furthermore, (Love, 2002a) found out that indirect cost of rework could be as much as five times the cost of rectification. There is a great need to reduce rework cost for projects performance and productivity level to improve (Love, 2002).

### **Rework in the Construction Industry**

The occurrence of rework obviously has an adverse effect and influence on project performance as it leads to cost and time overruns. Palaneeswaran (2006) upheld that rework has both direct and indirect impact on project performance. For example, in poorly managed projects, the gross impacts of rework (that is, both direct and indirect) could be equal to or even outdo the estimated profit margin levels. Likewise, in some cases there will be some carry forward ripple effects on different aspects such as stress, motivation, relationships and reputation. He acknowledged the following direct impact of rework on project management transactions: additional time to rework, additional costs for covering rework occurrences, additional materials for rework and subsequent wastage handling, and additional labour for rework and related extensions of supervising manpower. Love (2002b) resolved that rework can totally affect an individual, an organisation and a project's performance indirectly. Once design error is noticed and identified rework is inevitable. The extent of rework that emanate is however dependent upon when it was identified in the project life cycle (Lopez and Love 2012). Rework is a prominent factor that contributes negatively to the construction process and directly leads to client dissatisfaction, reduces profitability and in extreme conditions leads to hostile relationship between participants which could be settled either by arbitration or the court of law (Love, 2002a). Oyewobi and Ogunsemi (2010) emphasizes that a project must be well conceived, must start on a right note in order to end well. At the beginning of the planning stages, the building owner, the initiator of the contract and the designer must come together and plan the work appropriately in order to prevent the occurrence of rework. Inadequate planning can affect a well-conceived construction project, leaving all the participants, designers, clients and contractors, discontented at the completion of the project. Thus, as construction involves the execution of a design envisioned by the architects and engineers, ineffective implementation of this design process will inevitably lead to rework and result in time and cost overruns in both the design and construction phase (Oyewobi and Ogunsemi, 2010).

Rework occurs due to so many factors such as errors in design, construction failure and change order, inadequate coordination, ineffective and inefficient communication among stakeholders of the project (Oyewobi *et al*. 2011). It is found that owner change and design error/omission seems to be the root cause of rework having a relatively greater cost implication than the other factors aforementioned (Hwang *et al.*, 2009). Wasfy (2010) recorded that other causes of rework in construction projects includes; unskilled supervision, insufficient supervision, poor workmanship, improper subcontractor selection, inadequate work protection and inappropriate work sequencing.

The direct effect of rework on construction projects consist of; time overrun, this is the extra time taken to carry out rework, additional cost to rectify the defect, increased volume of materials as against the budgeted volume in other to carry out rework, wastages, increase in labour cost to make good defect (Palaneeswaran *et al*. 2005). Rework occurs more often in building works due to reasons which includes: different interface related issues e.g. lack of coordination between main building contractors and building services contractors, poor communication between design team and construction team (Palaneeswaran, 2006). The time frame of cost tracking includes the length of time rework is identified, the time required to carry out the rework and the time required to gear up and carry on with the original scope of work (Fayek *et al.*, 2003). Timely identification and correction of rework e.g. due to design error, defects, non-conformance are important for controlling the adverse effect of

rework on cost and time (Palaneeswaran, 2006). The root causes of rework can be grouped into different categories these are; client related factors, design related factors and contractor related factors including site management and contractor factors (Love and Edwards, 2004).

### **Causes of Rework**

According to Anjana and Christopher (2016), the causes of rework is classified under client related factors, design related factors, contractor related factors, site management and subcontractor's factors. The major factors that contributes to client related rework is poor communication between design consultants and the clients, this implies that there is little interaction between the clients and the design team consultants to make sure that the client ideas are communicated properly and due to this rework springs up right from the initiation stage, proceeding through an incubation system and at the long run manifesting itself during the implementation stage. The predominant factor that leads to design related rework is the changes made to the design at the request of the client, this means that most clients lack the required experience as regard the design process and as a result their ideas may not be feasible during the design. The site management related factors usually springs up due to inexperience and also the inability to effectively communicate with the subcontractors which leads to deviation from drawings, poor coordination of resources and setting out errors. Love et al. (2005) resolved that variations during the design process are frequently captured too late because of the successive communication structure of supply chains, and the lack of coordination and integration between design team members. The lack of coordination among design consultants led to major design-related changes which affected all the design firms involved. This subsequently resulted in changes on site, which affected most of the subcontractors.

### **Design Errors**

Tuker and Edmonson (2002) define design error as the carrying out of a task that is either unnecessary or incorrectly done. Furthermore, (Reason and Hobbs, 2003), define error as the failure of planned actions to achieve their desired goals, where this occurs without some unforeseeable or chance intervention. Design error is a deviation from a drawing or specification, also including omission and ambiguities. Failure is usually used interchangeably with error, but however there is a slight difference between expected and observed performance. (Ayininuola and Olalusi, 2004).

### **Sources of design error**

Mryyan and Tzortzopoulos (2013) identified the sources of design errors and it is classified under the following headings: errors attributed to the client, errors attributed to failure to implement regulations and building codes, errors attributed to lack of details in drawing and/or mis-interpretation of drawings.

### **Rework and Design Errors**

Previous studies have shown that substantial quantity of rework is design related (Love, 2005). This design related rework are changes made by different parties involved in the process which includes clients, contractors, subcontractors, end users and regulatory bodies. The design related factors as outlined by (Palaneeswaran,2006) includes factors such as;

- i. Ineffective use of quality management practices.
- ii. Ineffective use of information technology
- iii. Poor coordination between different design team members
- iv. Time boxing/fixed time for a task
- v. Poor planning of workload
- vi. Lack of manpower to complete the required task
- vii. Design team turnover/reallocation to other projects
- viii. Not enough time to prepare contract documents
- ix. Insufficient client brief to prepare detailed contract document.

### **Cost and Rework**

Love (2002b) suggested that design and construction organisations must implement a quality management system, supported by a quality cost system, in order to lessen the costs of rework. Only when organisations begin to measure their rework costs carefully will they fully appreciate the economic benefits of achieving high quality. Love (2002b) emphasized that there is a lack of uniformity in the manner in which rework cost data are collected due

to the various interpretations as to what constitutes rework. Barber *et al.* (2000) acknowledge that the cost of rework could be as high as 23% of the contract sum, with a number of factors contributing to rework cost. These factors according to Love (2002b) includes; the extent of quality management practices implemented, the type of project being executed, the method of procurement used and the complexity of the project. Love and Li (2000) found out that the cost of rework for a residential and industrial building was 3.15% and 2.40% respectively of the value of the contract sum. the economic benefits of recording incidences of rework and quantifying its costs have been overlooked.

**RESEARCH METHOD**

Data was collated from secondary and primary sources. Review of past literatures was used to obtain the root causes of rework and causes of design related rework of rework. The use of checklist to access archival data, such as original contract sum, final contract sum and cost of the rework carried out on the project. This was analysed using correlation analysis and relative importance index (RII). There was also collation of secondary data from books, past works of eminent scholars related to the topic under investigation. The population for the study is comprised of the construction companies registered with Abuja’s business directory which is 244 as at March 2017. Considering the population size identified, the sampling frame was limited to Abuja, questionnaires was distributed to registered construction companies with Abuja business directory. The sample size for the study from the study’s population (244) will be 71 based on Yamane, 1967 formula as given below using 10% level of accuracy, 95% certainty level, 50% level of inconstancy and a purposive sampling. From the entire population of this study which was 244, sixty-four (64) questionnaires were retrieved accounting for 90% of the limit set for the questionnaire which was seventy – one (71) questionnaires. also archival data of ten institutional building projects in Abuja was retrieved.

**RESULTS AND DISCUSSION**

There are three (3) variables in this research work. These variables were used in the process of analysing the raw data. They are; Initial Contract Sum, Final Contract Sum, Cost of Rework.

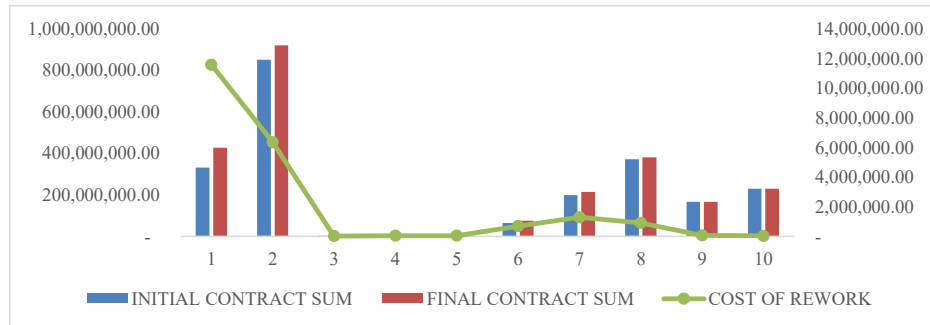


Figure 1.1: Initial Contract Sum, Final Contract Sum and Rework Cost  
Source: Researcher's Data Analysis (2017)

From figure 1.1 shows the initial contract sum, final contract sum and rework cost of the selected building projects. On average, it was discovered that the rework cost is quite significant.

**Table 1.1: Causes of Rework on Institutional Buildings**

Causes	1	2	3	4	5	RII	Rank
Design related factor	1	3	8	25	27	0.74	1 <sup>st</sup>
Client related factor	0	2	14	34	14	0.70	2 <sup>nd</sup>
Contractor related factor	0	2	24	33	5	0.65	3 <sup>rd</sup>
Sub-contractor related factor	0	9	43	11	1	0.54	4 <sup>th</sup>

Source: Researcher’s Analysis (2017)

Table 1.1 shows the ranking for the causes of rework that has occurred in the project executed by the respondents’ firm. Design related causes had the highest ranking thereby

coming 1<sup>st</sup> with RII of 0.74, followed by client related causes coming 2<sup>nd</sup> with RII of 0.70, contractor related causes came 3<sup>rd</sup> with RII of 0.65, lastly sub-contractor related with RII of 0.54. This shows that all the causes of rework are quite significant.

**Table 1.2: Causes of Design Related Rework on Institutional Buildings**

Causes	1	2	3	4	5	RII	Rank
Insufficient client brief to prepare detailed contract document	0	3	10	29	22	0.73	1st
Not enough time to prepare contract documents	0	7	16	33	8	0.65	2nd
Ineffective use of quality management practices	0	4	27	27	6	0.63	3rd
Poor coordination between different design team members	0	7	29	23	5	0.61	4th
Time boxing/fixed time for a task	0	8	33	22	1	0.58	5th
Ineffective use of information technology	1	13	28	18	4	0.56	6th
Design team turnover/reallocation to other projects	3	19	22	13	7	0.54	7th
Poor planning of workload	0	19	31	11	3	0.53	8th
Lack of manpower to complete the required task	6	19	28	9	2	0.48	9th

Source: Researcher’s Analysis (2017)

Table 1.2 shows the causes of design related rework on projects executed by the respondents. Insufficient client brief to prepare detailed contract document came 1<sup>st</sup> with RII of 0.73, Not enough time to prepare contract documents followed 2<sup>nd</sup> with RII of 0.65, Ineffective use of quality management practices, Poor coordination between different design team members, Time boxing/fixed time for a task, Ineffective use of information technology, Design team turnover/reallocation to other projects, Poor planning of workload and Lack of manpower to complete the required task came 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, 8<sup>th</sup> and 9<sup>th</sup> with RII of 0.63, 0.61, 0.58, 0.56, 0.54, 0.53 and 0.48 respectively. This shows that all the design related causes of rework are quite significant.

### Correlation Analysis

**Table 1.3: Correlation Matrix of the Relationship Between Rework Cost and the Selected Variables**

	Initial Contract Sum	Final Contract Sum	Rework Cost
Initial Contract Sum	1		
Final Contract Sum	.996**	1	
Rework Cost	.582	.652*	1

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

Source: Researcher’s Analysis (2017)

From table 1.3 shows correlation analysis results. The relationship between rework cost and the selected variables was examined using correlation, it was found that; rework cost and initial contract sum were moderately positively correlated,  $r(10) = 0.582, p = 0.077$  and rework cost and final contract sum were positively correlated,  $r(10) = 0.652, p = 0.041$ . This indicates that initial and final contract sum are affected by rework cost

### DISCUSSION OF RESULTS

The result of the analysis on the causes of rework shows that design related rework has the highest ranking with RII of 0.74, this is in line with the findings of Love (2005) which states that substantial quantity of rework is design related. This design related rework are changes made by different parties involved in the process which includes clients, contractors, subcontractors, end users and regulatory bodies. As construction involves the execution of a design envisioned by the architects and engineers, ineffective implementation of this design process will inevitably lead to rework and result in time and cost overruns in both the design and construction phase (Oyewobi and Ogunsemi, 2010). The causes of design related rework on projects executed by the respondents, shows that Insufficient client brief to prepare

detailed contract document came 1<sup>st</sup> with RII of 0.73, this also conforms to the findings of Hwang *et al* (2009) who stated that owner change and design error/omission seems to be the root cause of rework having a relatively greater cost implication. Not enough time to prepare contract documents followed 2<sup>nd</sup> with RII of 0.65, Ineffective use of quality management practices with RII of 0.63 came 3<sup>rd</sup>, while Poor coordination between different design team members has RII of 0.61.

The correlation analysis of the cost implication of rework indicates that the initial and final contract sum are significantly affected by rework cost in most scenario, when rework occur in construction project it increases the contract sum of such project which could either lead to project delay or abandonment in extreme cases.

## CONCLUSION

The study concludes that the root causes of rework which are classified as design related causes, client related causes, contractor related causes and sub-contractor related causes all have significant effect on project with design related factors taking the lead. This is because most times errors, omissions and ambiguity in design gives way for other factors to surface. Also it is concluded that the frequency of rework in building projects most especially institutional buildings which are mostly frame structures is quite high and also have a significant cost implication on the overall project as most of the design related rework is usually found on the structural components i.e. the columns, beams and slab.

It was also concluded that the initial and final contract sum are significantly affected by rework. The occurrence of rework changes the initial by increasing the final contract sum, this has an adverse effect on project delivery as it sometimes leads to project abandonment in worst scenarios and also extension of the completion time in less complicated scenarios.

Finally, the study also concludes that ways in which design related rework reduced have not really been adopted by most firm except for the increased use of computer aided design/engineering technologies. Other ways that has been identified from previous research to be very effective such as introduction of multidisciplinary design team and proper implementation of procurement strategies at the design stage have not been widely adopted. design related rework reduction is very keen if the construction industry to make headways and deliver quality projects to meet clients' satisfaction.

## RECOMMENDATIONS

It is recommended that the introduction of multidisciplinary design team during the design stage should be adopted by both clients and professionals so as to reduce the rate of errors, omission and ambiguity. Secondly, clients should be advised on the cost implications of frequent changes which usually leads to rework so as to get detailed client brief during the design stage before construction commences.

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