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Design-Related Causes of Rework and the Performance of Oil and Gas Projects in Nigeria

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Abstract

In recent times, the need to optimize project performance has been on the front burner of International Oil Companies, especially in developing countries. The quest for rework reduction to improve project performance underpins this research. This study assesses the frequency of occurrence of design-related causes of rework and its influence on project performance in terms of cost and time. A survey research design approach was adopted which involved a stratified random sample of 500 contractors and 385 consultants. Data were collected through structured questionnaire and analysed using Mean Item Score, Spearman Rank Correlation test, Kruskal Wallis test and One Sample T-test. The result shows that there is significant correlation between contractors and consultants' perceptions of the frequency of occurrence of design-related causes of rework. It also shows that design-related causes of rework have significant influence on project time and cost performance. In addition, the project team members ranked errors and omission in design document, ineffective communication between project team members, design changes, lack of site verification by design team and lack of as-built documentation as the top five frequently occurring design-related causes of rework in oil and gas projects. Furthermore, project location does not influence the frequency of occurrence of design-related causes of rework and its impact on the performance of oil and gas projects. It is concluded that there is need for effective design and quality management practices to enhance oil and gas project delivery. It is therefore recommended that construction professional in the oil and gas industry should implement design management surveillance and constructability reviews during the design phase as these are effective strategies to reduce design-related causes of rework which will lead to improved project performance in the oil and gas sector.

Keyword: *Design, Performance, Rework, Oil and Gas, Projects, Influence*

1.0 Introduction

The enormous economic contributions of the oil and gas industry to many developing economies makes its future of critical importance to the global community. The sector which has been pivotal to the economic growth of Nigeria has been faced with economic downturn in recent years. Amidst this challenge, there are instances of over-budget and behind schedule in oil and gas projects in developing economies, particularly in Nigeria [1, 2, 3]. While several studies [2,1,4] have identified causes of cost and schedule overrun in engineering and capital projects, one of the factor contributing to cost and schedule overruns in oil and gas projects is rework [5, 2].

Rework has been defined in extant literature as the exertion of unnecessary efforts and resources to redo a process or activity due to non-conformance to specification or as a result of wrongful execution of work the first time it was done [6, 7, 5]. In oil and gas projects' environments where several activities are undertaken simultaneously, rework can occur from errors, omissions,

failures, damage, and change orders. Since rework is performing a task more than once, it can occur at different stages throughout the project life cycle, either during design, fabrication, construction or installation phase.

Design-related factors have contributed to rework in oil and gas projects, these underlying causes among others are inadequate design, poor scope definition, lack of interface co-ordination, ineffective communication, inadequate design and engineering reviews, errors and omission [2]. Errors and omission originates because design consultants are often too quick to move on to the next phase of the project without detailed check and review of the design output and deliverables [8]. Poor production and management of contract documentation by contract administrators and the ineffective use of information technology during the design phase also results in rework in engineering and construction projects.

In view of this, there is a growing and continuous interest in the causes of rework related to design because of its impact on project performance. According to a study conducted by Reference [5], design-related causes of rework had the highest effect on heavy industrial project. Researchers have examined the frequency of occurrence of design-related causes of rework in different parts of the world. Notably, Reference [9] carried out a study on rework and reported that engineering and design reviews were the most frequently occurring causes of rework in heavy industrial project in Alberta. In the same vein, studies have assessed the influence of design-related causes of rework on project performance [10, 11, 8]. However, no similar work has been carried out in the Nigerian oil and gas sector which is the main stay of the nation's economy. Furthermore, previous works did not compare consultants and contractors' perceptions in the assessments of the frequency of occurrence of design-related causes of rework and their influence on project performance. Comparing consultants and contractors' perceptions on the subject matter will indicate their agreements or otherwise. This will consequently reveal most frequently occurring causes of rework based on their agreements and present a holistic approach to the appraisal of design-related causes of rework based on their disagreements.

The study area comprised of six states in the South-South Zone of Nigeria and is strategically located at the point where the river Niger joins the Atlantic Ocean through the Gulf of Guinea. The constituent states which forms the major part of the Niger delta region include: Bayelsa, Rivers, Akwa Ibom, Cross River, Edo and Delta States. Crude oil is the most extensive exploited mineral resources in the region. As a result of oil and gas activities in the region, a lot of capital projects are executed both in offshore and onshore location in the study area. The fact that projects executed in the region include facility modification, field redevelopment, green field development and infrastructural upgrades makes rework a subject of research interest. The major players in the oil and gas industry comprise of clients, contractors, project manager and consultants, out of which consultants and contractors play the dominant roles. Therefore, comparing consultants and contractors' perceptions in the different states which forms the study area will reveal whether or not location has effect on the frequency of occurrence and the influence of design-related causes of rework on project performance as perceived by contractors' and consultants'. Likewise, it will also show whether the two group of respondents agree or disagree concerning their perceptions of the subject matter.

Arising from the importance of the upstream oil and gas industry to Nigeria economy, the occurrence of rework may potentially impact on the delivery time and cost of oil and gas projects. It is against this backdrop that this study intends to examine the occurrence and influence of design-related causes of rework on project performance in South-South, Nigeria with a view to enhancing investment returns for stakeholders in the sector.

Objectives of the study

The objectives of the study are to:

1. determine contractors and consultants' perceptions of the frequency of occurrence of design-related causes of rework in oil and gas construction projects,
2. evaluate the influence of design-related causes of rework on project performance in terms of cost and time based on the perceptions of selected project team members, and

3. assess the influence of project location on the frequency of occurrence of design-related causes of rework and its impact on project performance as perceived by the selected project team members.

Hypotheses of the study

To achieve the objectives of the study, four hypotheses were formulated which state that:

H_1: There is no significant correlation between consultants' and contractors' perceptions of the frequency of occurrence of design-related causes of rework in oil and gas construction projects,

H_2: There is no significant correlation between consultants' and contractors' perceptions of the influence of design-related causes of rework on cost and time performance of oil and gas construction projects,

H_3: The influence of design-related causes of rework on time and cost performance is not significant,

H_4: The frequency of occurrence of design-related causes of rework in oil and gas construction projects do not vary significantly across the states in South-South Geo-Political Zone of Nigeria.

H_5: The influence of design-related causes of rework on cost and time performance of oil and gas construction projects do not vary significantly across the states in South-South Geo-Political Zone of Nigeria.

2.0 Review of Related Literature

2.1 Players in the Oil and Gas Industry

Previous studies have laid credence that parties involved in the projects contributes more to rework occurrence in construction projects (12, 5). As a result, Reference [12] alerted that rework in construction projects could originate from parties in the construction projects. The authors equally identified key project players contributing to rework in construction projects namely; client, consultant, and contractor. In construction projects, several stakeholders are involved at various stages of the project, performing different functions and roles with a view to achieving the project objective. The project team often comprises the design team and the building team [13]. Depending on the size of the project, the project team usually consists of architects, engineers and other consultants that produced the construction documents; the owner who can be a public or private entity that specifies the project requirements and makes available funding for design and construction; and the main contractor and subcontractors who are responsible for the physical construction of the project [14].

Even though both contractor and consultant play different roles in the delivery of construction projects, Reference [5] stated that, they have significant influence on rework occurrence. In another study, Reference [15] discovered that project players were the sources of design change, design error, design omission, construction error and construction omission, which caused rework in construction projects. Additionally, clients or their representatives have been noted as sources of rework in construction project because of their increasing expectations which usually result in changes [8, 5]. In view of this, consultants and contractors are considered to be an important member of the project team who are knowledgeable with the causes and impact of rework on oil and gas projects. Therefore, comparing consultants and contractor's perception of the occurrence and influence of design related causes of rework on project performance will provide a more holistic view of the frequency of occurrence and influence of design related causes of rework on project cost and time performance. The quest for excellence, waste elimination, and value creation underpins this research which is aimed at eliminating cost overruns, low productivity, schedule overrun in oil and gas construction projects from the Nigerian perspective.

2.2 Design Related Causes of Rework

Some studies have been carried out to uncover the causes of rework as it affects project delivery [7, 5, 2]. However, few studies have investigated the causes of design-related causes of rework in civil engineering and building projects [8; 15, 16]. In line with this, Reference [17] established that these changes which occurs in construction projects were mostly caused by clients

during the design stage and after some work had been undertaken on-site. Additionally, change orders have been acknowledged as a source of rework in construction projects [5]. Apart from changes requested by the client and design team, errors and omission which originates from design also generate unnecessary rework during construction [5, 2]. In the same way, changes made by contractors also generates significant rework during construction. Therefore, to mitigates this changes and document errors during design and construction, an effective communication between the clients and the project team is crucial. According to Reference [7], the construction of a facility is highly dependent on design, therefore, any error or omission in the design documents can affect the construction process.

To further investigate the cause of design-error induced rework, Reference [8] used system dynamics technique to discover that the pressure imposed upon design firms from their clients to produce detailed design documentation can lead to errors being made, which may not be identified until construction commences on-site. In the same vein, Reference [18] revealed that when projects are subjected to tight design schedules, design team members often reuse details and specifications to minimize their task loading. As a result, these practices lead to incomplete design information that may subsequently affect the construction process, resulting to rework. Furthermore, Reference [8] opined that ineffective communication between the client and design team can lead to design errors when the requirements are not clearly communicated to the designer.

Reference [18] added that Lack of effective use of information technologies, excessive involvement of client in the project, lack of clearly defined working procedures, poor communication, ineffective leadership and changes initiated by the contractor to improve quality were causes of rework in civil infrastructural projects. However, Reference [9] argued that rework caused by ineffective leadership and poor communication rarely occurs in construction project. On the contrary, Reference [19] stressed that poor communication between project team members could cause repeated rework. The authors further claimed that lack of understanding of the end user requirements and poor design coordination and interface could cause errors and omission that would lead to defects. Reference [2] reported that lack of design audit and review, lack of interface management, unrealistic schedule, poor project governance, lack of support among the professionals, staff turnover or continuity and lack of scope definitions were the causes of rework particularly in complex offshore hydrocarbon projects.

2.3 Influence of Rework on Project Performance

It is well established that project cost and schedule are core elements of project success [5, 18, 20]. However, previous studies have reported that rework contributes to cost and schedule overrun in construction projects [21, 5, 18]. The costs of rework in civil and heavy industrial engineering projects have been source of worries for construction stakeholders because the costs are gradually increasing [7]. For that reason, Reference [5] evaluated the influence of rework on cost performance using Total Field Rework Factor (TFRF). The result indicated that design errors had significant influence on the final cost of heavy industrial projects while design changes had significant influence on the final cost of light industrial projects. The authors concluded that design-related causes of rework were influential factor to cost overrun in heavy industrial projects. Reference [18] also reported that the magnitude of rework cases in construction projects was correlated with increase in project cost and schedule.

Studies have revealed that rework has significant impact on the performance of building and civil engineering projects [7, 22, 4]. In line with this finding, Reference [18] investigated 115 civil infrastructure projects and revealed that the mean direct and indirect rework costs were 5.07% and 5.22% of the contract value respectively. These rework costs were lower than those in building projects reported by Reference [7] who found that the direct and indirect rework costs were 6.44% and 5.6% of contract value, respectively. In South Africa, Reference [23] reported that rework cost for building project was 13% of project cost. In Nigeria, Reference [24] reported that time overrun and cost overrun on building project were 37.26% and 9.88% respectively. They also reported that the cost of rework was 3.47% of the contract value. In the same study, cost of rework for new building and

refurbished building in Nigeria was 5.06% and 3.23% of the contract value respectively. In oil and gas, Reference [2] revealed that rework significantly impacts the performance of oil and gas project. The authors reported that rework costs in offshore hydrocarbon projects were estimated to range from 3% to 25% of capital expenditure.

3.0 Methodology

Exploratory survey research design involving the use of structured questionnaire was employed in this study. The population of the study comprises contractors and consultants involved in the execution of oil and gas construction projects. A total of 667 contractors and 410 consultants were identified through pilot study and this served as the study population frame. The sample size for the study was determined using Taro Yamane formula for finite population which states:

$$n = \frac{\mathrm{N}}{1 + \mathrm{N(e)}^2}$$

Where n = Sample size; N = Finite Population; e = Level of significance (0.05) and 1 = Unity.

Sample sizes of 500 contractors and 385 consultants were obtained which were randomly sampled from the study population size.

Structured questionnaires were used to collect data on the frequency of occurrence and relative influence of twenty-two identified design-related causes of rework from two selected project team members which constitute the respondents for the study. The frequency of occurrence of the design-related causes of rework and its influence on time and cost performance was measured on a five point Likert-scale namely: nill, low, moderate, high and very high. Weights were assigned to the scale as follows: nill=1, low=2, moderate=3, high=4 and very high=5. Out of 885 copies of questionnaire administered on the sampled study population through stratified random sampling techniques, 800 correctly completed questionnaire comprising of 458 contractors and 342 consultants were used for the analysis.

Data collected were analysed using Statistical package for social science (SPSS) version 24. The frequency of occurrence of design-related causes of rework and its influence on time and cost performance of oil and gas construction projects were analysed using Mean Item Score (MIS). Spearman Rank Correlation was used to test the agreement of contractors and consultants on the frequency of occurrence and influence of design-related causes of rework on cost and time performance. Kruskal-Wallis H test was used to evaluate the difference in perceptions of contractors and consultants across the six states that constitute the study area. The decision rule for testing hypothesis is that, if P-value is less than (or equal to) α at 5% level of significance, then the null hypothesis is rejected in favour of the alternate hypothesis. The decision rule used in this study is stated below: If $P \leq 0.05$, reject H_0 otherwise, If $P > 0.05$, then fail to reject H_0.

Likert scale data has been considered as ordinal scale data, however, previous studies have adopted parametric statistical methods such as the t-test for analysing the data [15, 25]. Although, Reference [26] believed that there is no basis to analyse parametric statistics using ordinal level data when the assumptions are not met. Reference [27] argued that parametric statistics can be used to analyse Likert data with unequal variances and non-normal distributions, without fear of coming to wrong conclusions. Therefore, this study adopts one sample t-test using a hypothesised mean ($\mu = 3$) to test the significance of the influence of design-related causes of rework on cost and time performance in line with related previous studies [15, 25]. The decision rule is that if the MS of all design-related factors are equal or greater than the hypothesised MS then the factors are considered to have significant influence on cost and time performance (i.e. p-value $\leq$ 0.05). Otherwise it will be insignificant as will be indicated by p-value that is greater than the critical value of 0.05 (i.e. p-value >0.05).

Mean Item Score was obtained by dividing the total score by the number of the respondent for each of the design-related causes of rework. The average of the (MIS) was used to determine the most frequently occurring design-related causes of rework. Mean Item Scores equal to or above the average

(MIS) was considered the most frequently occurring design-related causes of rework. Similarly, the average of the (MIS) was used to determine the design-related causes of rework having significant influence on cost and time performance. Mean Item Scores equal to or above the average (MIS) was regarded as significant.

Cronbach's alpha was used to assess the reliability of the scale in the questionnaire. Cronbach's alpha of 0.7 and above [28] was adopted for testing the internal consistency of the scale in the questionnaire. Table 1 shows excerpts from SPSS output of Cronbach's alpha of the scale administered to both contractor and consultants which indicate that the reliability of the scales is acceptable being above 0.7 - consultant=0.922, contractor=0.930.

Table 1: Cronbach's Alpha of scale of item administered to both consultant and contractor

Number of Items	Cronbach's Alpha of Scale of Item Administered to Consultant	Cronbach's Alpha of Scale of Item Administered to Contractor
22	0.922	0.930

4.0 Results and Discussions

Data obtained on a five point Likert scale from the structured questionnaire were collated and analysed using appropriate statistical tools as described in the methodology. The results of data analysis carried out to achieve the objectives of the study are presented below.

4.1 Contractors and Consultants' Perceptions of the Frequency of Occurrence of Design-Related Causes of Rework in Oil and Gas Construction Projects

The first objective of the study is to determine consultants and contractor's perceptions of the frequency of occurrence of design-related causes of rework in oil and gas projects. Data collected on the perceptions of consultants and contractors on the frequency of occurrence of each of the twenty-two design-related causes of rework in oil and gas projects were analysed to derive their Mean Item Score and ranks. Results are presented in Table 2

Table 2: Consultants and contractors' perceptions of the frequency of occurrence of design-related causes of rework in oil and gas construction projects

Design-related causes of rework	Consultant (N=342)			Contractor (N=458)		
	Sum	Mean Item Score	Rank	Sum	Mean Item Score	Rank
Error and omission in design document	1365	3.99	1*	1933	4.22	1*
Ineffective communication	1279	3.74	2*	1873	4.09	2*
Lack of site verification by design team prior to detailed design	1272	3.72	3*	1832	4	3*
Design changes	1207	3.53	7*	1805	3.94	4*
Lack of as-built documentation	1211	3.54	6*	1782	3.89	5*
Incomplete design review	937	2.74	20	1754	3.83	6*
Incomplete preliminary and detailed design	1173	3.43	9*	1754	3.83	7*
Inaccurate assumption during design	1146	3.35	10*	1745	3.81	8*
Lack of understanding of end-user requirement	1146	3.35	11*	1690	3.69	9*
Ineffective use of information technology and design software	1224	3.58	5*	1649	3.6	10*
Insufficient time for engineering activities	1176	3.44	8*	1608	3.51	11*
Incomplete project scope definition by client	1241	3.63	4*	1562	3.41	12

Design-related causes of rework	Consultant (N=342)			Contractor (N=458)		
	Sum	Mean Item Score	Rank	Sum	Mean Item Score	Rank
Complex specification	1105	3.23	13	1553	3.39	13
Poor production and management of contract document	1142	3.34	12*	1534	3.35	14
Wrong contracting strategy	1053	3.08	15	1475	3.22	15
Lack of skill and technical knowledge	1105	3.23	14	1461	3.19	16
Poor planning and allocation of design resources	1009	2.95	16	1351	2.95	17
High work load	923	2.7	23	1282	2.8	18
Ineffective design change control	930	2.72	22	1273	2.78	19
Inexperience design team	941	2.75	19	1273	2.78	20
Ineffective use of design quality management practice	988	2.89	17	1264	2.76	21
Inadequate constructability review	947	2.77	18	1232	2.69	22
Average Mean Item Score		3.26			3.44	

* = Most Frequently Occurring

The result in Table 2 indicates that consultants consider twelve (12) design-related factors having (MIS) ≥ 3.26 as most frequently occurring design-related causes of rework and the remaining ten (10) design-related factors as least occurring design-related causes of rework in oil and gas construction projects. Similarly, contractors consider eleven (11) design-related factors having (MIS) ≥ 3.44 as most frequently occurring design-related causes of rework and the remaining ten (10) design-related factors as least occurring design-related causes of rework in oil and gas construction projects. Ranks of the frequency of occurrence of other design-related causes of rework are as indicated in Table 2.

4.2 Spearman's Test of Correlation between Contractors' and Consultants' Perceptions of the Frequency of Occurrence of Design-Related Causes of Rework

To test the first hypothesis of the study, contractors and consultants' perception of the frequency of occurrence of design-related causes of rework in oil and gas projects were compared for agreement using Spearman's Test of correlation. Result of the test of hypothesis is presented in Table 3.

Table 3: Spearman test of correlation between contractors and consultant's perception

Parameter Correlated	N	r	P-value	decision
Contractors' and consultant's perception of the frequency of occurrence of design-related cause of rework on oil and gas projects	22	0.793	0.000	Reject

r = correlation coefficient

The result in Table 3 shows that p-value is less than the critical value ($p < 0.001$), therefore, the null hypothesis is rejected. The implication of this result is that both contractors and consultants agree and have similar views on the frequency of occurrence of each of the design-related causes of rework in oil and gas projects in Nigeria.

4.3 Selected Team Members' Perceptions of the Frequency of Occurrence of Design-Related Causes of Rework in Oil and Gas Construction Projects

Having concluded that there is agreement between consultants and contractors' perception of the frequency of occurrence of design-related causes of rework in oil and gas construction projects, data collected from the two selected project team members were combined and analysed to form selected team members' perceptions of the frequency of occurrence of design-related causes of rework in oil and gas projects. Results are presented in Table 4

The result in Table 4 indicates that out of twelve (12) design-related factors having (MIS) ≥ 3.37, 'errors and omission in design documents', 'ineffective communication', 'lack of site verification by design team prior to detailed design', 'design changes' and 'lack of as-built documentation' are the five most frequently occurring design-related causes of rework in oil and gas construction projects. The ranking of design changes, and errors and omissions among the most frequently occurring causes of rework supports the findings in previous studies which emphasised the importance of these factors [29, 15]. Similarly, Reference [30] also revealed that errors and omissions in engineering and design documents frequently occurs in industrial projects in Alberta. In line with Reference [15] where changes in plans or scope ranked second in most frequently occurring causes of rework, this study ranked design changes fourth most frequently occurring design-related causes of rework. Reference [19] reported that lack of communication between the client and design team members often lead to error and omission in project documentation. Therefore, the need to understand client's expectation and requirements becomes more imperative at the early phase of the project [31]. In view of this, project team members considered ineffective communication as the second most frequently occurring design-related causes of rework in oil and gas projects.

Table 4: Selected team members' perceptions of the frequency of occurrence of design-related causes of rework in oil and gas construction projects

Design-related causes of rework	Mean Item		
	Sum	Score	Rank
Error and omission in design document	3296	4.12	1*
Ineffective communication	3152	3.94	2*
Lack of site verification by design team prior to detailed design	3104	3.88	3*
Design changes	3016	3.77	4*
Lack of as-built documentation	2992	3.74	5*
Incomplete preliminary and detailed design	2928	3.66	6*
Inaccurate assumption during design	2896	3.62	7*
Ineffective use of information technology and design software	2872	3.59	8*
Lack of understanding of end-user requirement	2832	3.54	9*
Incomplete project scope definition by client	2808	3.51	10*
Insufficient time for engineering activities	2784	3.48	11*
Incomplete design review	2696	3.37	12*
Poor production and management of contract document	2672	3.34	13
Complex specification	2656	3.32	14
Lack of skill and technical knowledge	2568	3.21	15
Wrong contracting strategy	2528	3.16	16
Poor planning and allocation of design resources	2360	2.95	17
Ineffective use of design quality management practice	2248	2.81	18
Inexperience design team	2216	2.77	19

Design-related causes of rework	Sum	Mean Item Score	Rank
High work load	2208	2.76	20
Ineffective design change control	2208	2.76	21
Inadequate constructability review	2184	2.73	22
Average MIS		3.37	

N = 800; * = Most Frequently Occurring

According to Reference [19], the early involvement of the client in design process together with effective communication between the client and their design team are strategies to reduce design-related rework. These findings however underscore the need for effective constructability and design reviews during project planning stage. This study considered lack of site verification prior to detailed design as the third most occurring design-related causes of rework in oil and gas projects. This finding supports previous related study by Reference [30] where inadequate field verification by designer frequently occurred in heavy industrial projects. According to Reference [32], there are instances where time crashing does not permit contractors to go for detailed site verification, therefore they rely on visual inspection or local knowledge of the people in the area, if it is done at all. Hence, deficiencies in construction may occur as a result of failures of design or contract documents to capture such unforeseen circumstance. Lack of brownfield site verification by design team could be attributed to inadequate access to work location as most offshore location in Nigeria has limited access to personnel for some specific job. For this reason, adequate measure should be put in place to carry out brownfield site verification prior to detailed design to avoid unnecessary rework during construction.

4.4 Influence of Design-Related Causes of Rework on Cost and Time Performance of Oil and Gas Construction Projects

The second objective of the study is to determine the influence of design-related causes of rework on cost and time performance of oil and gas projects based on consultants and contractor's perceptions. Data collected on the perceptions of consultants and contractors on the influence of twenty-two design-related factors on project time and cost were analysed to derive their Mean Item Score and ranks. Results are presented in Table 5

Table 5: Consultants and contractors' perceptions of the influence of design-related causes of rework on project time and cost performance

	Time Performance				Cost Performance			
	Consultant (N=342)		Contractor (N=458)		Contractor (N=458)		Consultant (N=342)	
Design-related causes of rework	MIS	Rank	MIS	Rank	MIS	Rank	MIS	Rank
Error and omission in design document	4.26	1*	4.01	2*	4.08	2*	4.2	1*
Ineffective communication	4.22	2*	3.58	6*	3.56	6*	4.1	2*
Lack of site verification by design team prior to detailed design	4.10	3*	4.41	1*	4.43	1*	3.61	3*
Design changes	3.98	4*	3.78	4*	3.77	4*	3.6	4*
Lack of as-built documentation	3.78	5*	3.40	7*	3.50	7*	3.79	5*
Incomplete preliminary and detailed design	3.72	6*	3.88	3*	3.90	3*	3.56	6*
Inaccurate assumption during design	3.60	7*	3.52	5*	3.54	5*	3.44	7*
Ineffective use of information technology and design software	3.50	8*	2.84	11	2.83	11	3.34	8*
Lack of understanding of end-user	3.41	9*	3.21	9*	3.23	9*	3.28	9*

	Time Performance				Cost Performance			
	Consultant (N=342)		Contractor (N=458)		Contractor (N=458)		Consultant (N=342)	
Design-related causes of rework	MIS	Rank	MIS	Rank	MIS	Rank	MIS	Rank
requirement								
Incomplete project scope definition by client	3.40	10*	2.82	12	2.85	12	3.23	10
Insufficient time for engineering activities	3.20	11	3.35	8*	3.38	8*	3.17	11
Incomplete design review	3.12	12	3.01	10*	3.02	10	3.13	12
Poor production and management of contract document	3.01	13	2.71	13	2.70	13	3.1	13
Complex specification	2.94	14	2.62	14	2.64	14	3.08	14
Lack of skill and technical knowledge	2.89	15	2.38	18	2.38	18	3.07	15
Wrong contracting strategy	2.71	16	2.35	19	2.35	19	3.02	16
Poor planning and allocation of design resources	2.68	17	2.41	17	2.43	17	2.95	17
Ineffective use of design quality management practice	2.54	18	2.51	15	2.58	15	2.89	18
Inexperience design team	2.54	18	2.21	22	2.23	22	2.8	19
High work load	2.44	19	2.45	16	2.47	16	2.77	20
Ineffective design change control	2.32	21	2.25	21	2.37	21	2.74	21
Inadequate constructability review	2.28	22	2.3	20	2.33	20	2.73	22
Average (MIS)	**3.21**		**3.00**		**3.03**		**3.25**	

* Significant Influence

The result in Table 5 indicates that consultants considered ten (10) design-related factors having (MIS) $\geq$ 3.21 to have significant influence on project time performance. Similarly, contractors considered ten (10) design-related factors having (MIS) $\geq$ 3.00 to have significant influence on project time performance. On the other hand, consultants consider nine (9) design-related factors having (MIS) $\geq$ 3.25 to have significant influence on project cost performance. Equally, contractors considered nine (9) design-related factors having (MIS) $\geq$ 3.03 to have significant influence on project time performance. Ranks of the influence of other design-related causes of rework on time and cost performances of oil and gas projects are indicated in Table 5.

To test the second hypothesis of the study, contractors and consultants' perception of the influence of design-related causes of rework on project time and cost performance were compared for agreement using Spearman's Test of correlation. Result of the test of hypothesis is presented in Table 6.

Table 6: Spearman test of correlation between contractors and consultant's perception of the influence of design-related causes of rework on project performance

Parameter Correlated	N	r	*p*-value	decision
Time Performance	22	0.934	0.000	Reject
Cost Performance	22	0.921	0.000	Reject

r = correlation coefficient; N= Number of factors

The result shows that p-value is less than the critical value ($p < 0.001$), therefore, the null hypothesis is rejected. This result implies that both contractors and consultants agree and have similar

views on the influence of design-related causes of rework on time and cost performance of oil and gas projects in Nigeria. This result supports the findings of Reference [5], where it was reported that two groups of respondents (Owner and contractor) agrees that design errors have significant impact on cost performance of heavy industrial project while design change have significant influence on cost performance of light industrial project. Along the same vein, the result of the artificial neural network analysis (ANN) carried out on contractor's responses in a study by Reference [33] indicated that design-related causes of rework predict project time and cost performance.

4.5 Selected Team Members' Perceptions of the Influence of Design-Related Causes of Rework on Cost and Time Performance of Oil and Gas Projects

Similarly, because there is agreement between consultants and contractors on the influence of design-related causes of rework on time and cost performance of oil and gas construction projects, data collected from the two selected project team members were combined and analysed to represent selected team members' perceptions. Results are presented in Table 7.

The result in Table 7 indicates that out of eleven (11) design-related factors having (MIS) $\geq$ 3.34, 'errors and omission in design documents', 'lack of site verification by design team prior to detailed design', 'ineffective communication', 'inaccurate assumption during design', and 'design changes' are the top five design-related factors having influence on time performance of oil and gas construction projects. The result in Table 7 also shows that out of twelve (12) design-related factors having (MIS) $\geq$ 3.33, 'errors and omission in design documents', 'ineffective communication', 'design changes', 'lack of as-built documentation' and 'lack of site verification by design team prior to detailed design' are the top five design-related factors having influence on cost performance of oil and gas construction projects. Ranks of influence of other design-related causes of rework on cost and time performance of oil and gas construction projects according to selected team members' perceptions are as shown in Table 7.

Table 7: Stakeholder's perceptions of the influence of design related causes of rework on cost and time performance.

	Time Performance		Cost Performance	
Design-related causes of rework	MIS	Rank	MIS	Rank
Error and omission in design document	4.40	1*	4.35	1*
Ineffective communication	4.29	3*	4.32	2*
Lack of site verification by design team prior to detailed design	4.38	2*	4.30	3*
Design changes	4.18	5*	4.25	4*
Lack of as-built documentation	4.10	6*	4.12	5*
Incomplete preliminary and detailed design	3.60	9*	3.98	6*
Inaccurate assumption during design	4.27	4*	3.85	7
Ineffective use of information technology and design software	3.90	7*	3.73	8*
Lack of understanding of end-user requirement	3.85	8*	3.64	9*
Incomplete project scope definition by client	3.55	10*	3.54	10*
Inaccurate assumption during design	3.30	12	3.45	11*
Incomplete design review	3.35	11*	3.34	12*
Poor production and management of contract document	2.74	15	3.24	13
Complex specification	3.02	13	3.07	14
Lack of skill and technical knowledge	2.72	16	2.78	15

	Time Performance		Cost Performance	
Design-related causes of rework	MIS	Rank	MIS	Rank
Wrong contracting strategy	2.77	14	2.70	16
Poor planning and allocation of design resources	2.66	18	2.69	17
Ineffective use of design quality management practice	2.66	19	2.66	18
Inexperience design team	2.70	17	2.51	19
High work load	2.40	20	2.30	20
Ineffective design change control	2.28	21	2.30	21
Inadequate constructability review	2.30	22	2.16	22
Average MIS	**3.34**		**3.33**	

N = 800; * Significant Influence

4.6 T-test of Significance of the Influence of Design-Related Causes of Rework on Cost and Time Performance.

The significance of the influence of twenty-two design-related causes of rework on time and cost performance was tested using One-Sample t-test. One sample t-test was used to analyse the third hypothesis which states that: The influence of design-related causes of rework on time and cost performance is not significant. Results are presented in Table 8

Table 8: Results of one sample t-test of the influence of design-related causes of rework on cost and time performance

	Test value = 3				95% confidence interval of the difference		
	Performance variables	N	Mean	Mean Diff	Lower	Upper	P-Value
Influence of design-related causes of rework	Time	22	3.34	0.337	0.0086	0.666	0.046
	Cost	22	3.33	0.331	0.0066	0.655	0.045

N = numbers of factors

The result in Table 8 shows that p-values (0.046 and 0.045) are less than the critical value of 0.05 ($p < 0.05$) hence, the null hypothesis is rejected, implying that design-related causes of rework have significant influence on project time and cost performance of oil and gas construction projects. This result is in line with Reference [18] where the effect of rework occurrence on project cost performance showed significant correlation. The report of Reference [34] - that design rework impact time and cost performance of construction project also lends credence to the finding of this study. However, Reference [35] reported that rework could occur in project but not necessarily lead to cost overrun. Contrarily, Reference [18] stated that the magnitude of rework cases in construction projects was correlated with increase in project cost and schedule. Along the same line, Reference [15] indicated that rework have significant impact on building project performance.

This study also agrees with Reference [16] where design-related changes were the leading factor affecting schedule performance in construction industry. More so, this study corroborates findings from previous related studies where it was discovered that rework significantly contributes to project cost and schedule overrun [21, 5, 36]. The significant of this result is that it will guide construction professionals in the development of stringent measures in addressing those significant design-related causes of rework to optimise project performance.

4.7 Influence of Project Location on the Frequency of Occurrence of Design-Related Causes of Rework and its Impact on Project Performance

Having determined the combined views of the two project team members on the frequency of occurrence of design-related causes of rework, the perceptions of the two project team members in the six states that constitute the study area were analysed to assess the effect of location on the frequency of occurrence of design-related causes of rework. To achieve this, Kruskal-Wallis test was performed to test variation in the frequency of occurrence of design-related causes of rework in oil and gas projects across the different states in South-South Geo-Political Zone of Nigeria based on consultants' and contractors' perceptions. Result of the Kruskal-Wallis test is presented in Table 9

Table 9: Kruskal-Wallis (H) test of variation in the frequency of occurrence of design-related causes of rework across states in south-south, Nigeria

Location of Study	N	Frequency of Occurrence as perceived by consultants				Frequency of Occurrence as perceived by contractors			
		Mean Rank	Test Statistic	*p*-value	Decision	Mean Rank	Test Statistic	*p*-value	Decision
CRS	22	85.09				86.70			
RVS	22	57.80				56.91			
DES	22	66.14	7.661	0.176	Accept	72.52	10.560	0.061	Accept
EDS	22	57.39				54.16			
BYS	22	65.09				63.36			
AKS	22	67.50				65.34			
Total	132								

CRS= Cross River State; AKS= Akwa Ibom State; EDS= Edo State; BYS= Bayelsa State; RVS= Rivers State; DES= Delta State. N=Number of Factors

The result of Kruskal-Wallis H test in Table 9 shows that the difference in frequency of occurrence of design-related causes of rework as perceived by contractor and consultants is not significant, $\chi^2(5) = 7.661$, $P = 0.176$ and $\chi^2(5) = 10.560$, $P = 0.061$ respectively. Arising from this, the test fails to reject the null hypothesis and it was inferred that the influence of location on the frequency of occurrence of design-related causes of rework as perceived by consultants and contractors is not significant.

Similarly, the effect of location on the influence of design-related causes of rework on time and cost performance of oil and gas construction projects was evaluated using Kruskal-Wallis test. Result of the Kruskal-Wallis test is presented in Table 10.

Table 10: Kruskal-Wallis (H) test of variation in the influence of design-related causes of rework on cost and time performance across states in south-south, Nigeria

Respondents	Location of Study	N	Time Performance				Cost performance			
			Mean Rank	Test Statistic	*p*-value	Decision	Mean Rank	Test Statistic	*p*-value	Decision
Contractors	CRS	22	68.45				62.35			
	RVS	22	68.20				63.45			
	DES	22	55.07	8.413	0.135	Accept	59.09	7.212	0.324	Accept
	EDS	22	61.27				62.58			
	BYS	22	60.59				56.95			
	AKS	22	85.41				86.20			
Consultants	CRS	22	61.00				63.74			
	RVS	22	79.45				82.15			

Respondents	Location of Study	N	Time Performance				Cost performance			
			Mean Rank	Test Statistic	*p*-value	Decision	Mean Rank	Test Statistic	*p*-value	Decision
	DES	22	57.09	6.703	0.244	Accept	59.21	6.204	0.278	Accept
	EDS	22	72.86				71.23			
	BYS	22	56.95				55.63			
	AKS	22	71.64				72.01			

CRS= Cross River State; AKS= Akwa Ibom State; EDS= Edo State; BYS= Bayelsa State; RVS= Rivers State; DES= Delta State. N=Number of Factors

The result of Kruskal-Wallis H test in Table 10 shows that the difference in influence of design-related causes of rework on time and cost performance as perceived by contractors and contractor is not significant, χ^2 (5) =8.413, *P*=0.135; χ^2 (5) =6.703, *P*=0.244; χ^2 (5) =6.703, *P*=0.244 and χ^2 (5) =6.204, *P*=0.278 respectively. Arising from this, the test fails to reject the null hypothesis and it was inferred that the influence of design-related causes of rework on project time and cost performance of oil and gas projects across the six states in South-South Geo-Political Zone of Nigeria as perceived by contractors and consultants are the same.

The implication of this is that consultant and contractors do not consider influence of design-related causes of rework on time and cost performance to be different across project locations. In other words, project locations do not appear to have effect on the influence of design-related causes of rework on time and cost performance of oil and gas project. The result of this study agrees with the findings of Reference [5], where it was reported that the impact of design error and changes on cost performance was not influenced by location. Furthermore, previous studies have revealed that the influence of rework on performance are not significantly different across regions [21, 18, 2]. The significance of this result is that it will encourage construction professional not to concern themselves with the influence of design-related causes of rework on time and cost performances at different project locations, especially when they are across different states.

5.0 Conclusions and Recommendations

This study concludes that consultants and contractors' perceptions of the frequency of occurrence of design related causes of rework is the same. Therefore, both contractors and consultants agree on the design-related causes of rework that frequently occurs in oil and gas projects. In view of this, errors and omission in design document, ineffective communication, lack of site verification by design team, design changes and lack of as-built documentation are the five most frequently occurring design-related causes of rework in oil and gas projects in Nigeria. This study also concludes that the five most frequently occurring design-related causes of rework have significant influence on cost performance of oil and gas projects. The implication of this result is that their combined opinion on the frequency of occurrence and influence of design-related causes of rework on cost performance could serve as input in the development of strategies that will prevent the occurrence of design-related rework in oil and gas project.

This study also concludes that contractors and consultants' perception of the influence of design-related causes of rework on project time and cost performance is the same. As a result, errors and omission in design documents, lack of site verification by design team prior to detailed design, ineffective communication, inaccurate assumption during design, and design changes are the top five design-related factors having influence on time performance of oil and gas construction projects as perceived by project team members.

Furthermore, this study concludes that the frequency of occurrence and influence of design-related causes of rework across the states of South-South, Nigeria as perceived by contractor and consultant are the same. This implies that location has no effect on the frequency of occurrence and influence of design-related causes of rework on time and cost performance of oil and gas projects. In

addition, this study concludes that design-related causes of rework have significant influence on project time and cost performance. In view of this, time and cost performance of Oil and Gas construction projects could be enhanced by mitigating design-related causes of rework.

The study observes the need for effective design and quality management practices to enhance oil and gas project delivery. It is therefore recommended that construction professional in the oil and gas industry should implement design management surveillance and constructability reviews during the design phase as these are effective strategies to reduce design-related causes of rework which will lead to improved project performance in the oil and gas sector.

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