Transactions of the Korean Nuclear Society Virtual Autumn Meeting
October 21-22, 2021

Design Change in Ghanaian Power Projects: Identifying Important Cause Factors

Elikplim Afelete, Wooyong Jung*
KINGS, Department of NPP Engineering, 658-91 Haemaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 45014
**Corresponding author:wooyong@kings.ac.kr*

1. Introduction

The construction industry is a critical component of any country's growth and an important metric for evaluating its economic output[1]. Unfortunately, challenges arising from the design and construction phases of projects, such as design changes, are causing delays and cost overruns in the industry. Design change occur in every project including power projects. Previous studies have covered much ground when it comes to design changes and has focused on a number of important topics such as cause and impact of design change[2][3][4], effects of design change on cost[5],[6], and effects of design changes on schedule[5]. Nonetheless, previous studies have paid less attention to the subject of design change in power projects. As a result, design changes in power projects are the focus of this study. For the purposes of this study, 30 causes for design changes were identified after a literature analysis and expert feedback; additionally, power projects were categorized into three project-type subcategories. They are power plant, renewable, and distribution and transmission subdivisions. The objective of this study is to identify separately for each power project type important cause factors affecting design changes and to understand the relationships that exists among them. This study will be helpful for future energy projects including nuclear power plants that the country will undertake.

2. Design change

There is no single definition for what design change means, as previous scholars have each interpreted it differently. For example, [5]Defines design change as any modification to a project's design or construction after the contract has been awarded. [4] Also defines design change as any change to the scope of work as highlighted by the contract document following the creation of legal relations between the principal and the contractor. Modifications to the design, quality, and quantity of work, as well as changes to standards and materials utilized in the job as defined by [7].According to [8], design change is the most influential change causing factor in the construction phase. Changes in design would invariably have a negative impact on project performance, [9] therefore concludes that time-cost overruns of 5-20% are due to design change in residential construction projects. Similarly,[10] also concluded that the cost of project increased at an average between 11% to 15% due to change orders. Design change is likely to occur at the design phase of the project life cycle and the construction phase.

3. Methods

The methods used to collect data for this research are interviews and questionnaire survey. To identify and interpret the study's objectives, the research used a mixed methodology approach, depending largely on qualitative and quantitative research methodologies. A two section questionnaire was designed constructively to identify important cause factors among the 30 causes described in Table 2. The causes are ranked using a 5-likert scale for each subdivision, as per the study's objective. Questionnaires were distributed to respondents in the power industry. Table 1 represents details of the number of questionnaires sent and received from respondents.

Number of respondents	
Questionnaire distributed to respondents	156
Responds valid for analysis	129
Power plant Project	45
Renewable Project	42
Distribution Project	42

Table 1 . Questionnaire statistics

Data received is analyzed using statistical package for social sciences software, SPSS to determine the mean of each cause factor for the subdivisions. To determine the mean value for each cause factor, a one-way analysis of variance (ANOVA) is used. Analysis of variance (ANOVA) is a statistical test for detecting differences in group means when there is one parametric dependent variable and one or more independent variables[11].

3.1. Reliability Test

To ensure reliability of questionnaire, Cronbach's Alpha value, Cα for data is tested. The minimum acceptable value for data reliability, $C\alpha > 0.7$ [12]. Cronbach's Alpha value for data is 0.941, thus data is reliable.

3.2. Causes of design change in power projects

The 30 identified causes are divided into controllable and uncontrollable factors. Controllable factors are subdivided into owner-related, contractor-related and design-related as shown from the figure above. There are 25 controllable causes and 5 uncontrollable causes. 11 cause factors are owner-related, 8 are contractor-related and 6 are design-related as shown in Table 1 below.

No.		Description	Reference
	Controllable Factors		
	Owner-Related		
1	Change of Plans	Frequent revisions made by the owner, either at the initial or later in the project's life cycle, which have an impact on the project's scope.	[13],[14],[9]
2	Technology changes	Highlights problem that occur as a result of introduction of new technology.	[8],[9],[15]
3	Conflict between contract documents	Discrepancy or inconsistency between initial terms of agreement mostly at the progressive phase of the project.	[4],[13],[16],[8],[15]
4	Lack of technical knowledge to comprehend and visualize project	When the owner (owner’s consultant) in most cases lacks the expertise and experience in understanding the project.	[17], Expert Opinion
5	Financial problems	Lack of funds or bankruptcy by the owner to continue the project	[13],[16],[9],[15]
6	Poor project objective definition	This is the case where owner fails to vividly define the scope of the project to the designer or contractor.	[8],[9],[4]
7	Long decision making time	Taking a lengthy time to define and make decisions has an impact on the design and construction process.	[17], [13],[9]
8	Additional work	In certain cases, the owner adds more work to the initial scope.	[13],[14],[15]
9	Change of designers	In some projects, designer is replaced with a different designer.	[4], [9]
10	Estimation errors	Poorly or wrongly estimating the amount of resources and materials needed for project.	[8], [9], [15]
11	Ineffective supervision	When the owner fails to keep a close eye on the design and construction process.	[4],[14],[1]
	Contractor-Related		
12	Equipment and Material failure	Machine and equipment breakdown due to poor operation.	[13], [29]
13	Health and Safety considerations	When a contractor believes his or her safety is being jeopardized, safety design elements are subject to additional consideration.	[13],[8],[9]
14	Lack of coordination and communication	Poor communication and coordination among project stakeholders, as well as late information dissemination	[13],[8], [14] ,[15] ,[1] ,[4]
15	Deficient resources in quality and quantity	Describes when there is no available resource (Human and material). Also, low quality material and inexperienced human resource	Expert Opinion
16	Inadequate construction experience	Contractors lack the necessary experience to manage and build such projects.	[16], [13]
17	Lack of awareness about governmental regulations, statues and their modification	Lack of awareness of current and evolving legislation and government laws affecting such projects.	[17], [13]

18	Inadequate pre-construction study and review of design documents	Contractor fails to thoroughly evaluate design documentation before starting work.	[5], [4],[14],[1]
19	Contractor's desire to improve their financial situation	When a contractor attempts to make a lot of money to compensate for their low financial status.	[8]
	Design-Related		
20	Design complexity	Projects involving power plants often need a large number of labor and design activities. This complicates design work by adding a lot of complexities and information.	[13],[14] ,[1]
21	Errors and Omission in design	Making mistakes during the design process or omitting to include important data and information.	[13],[16],[8],[14],[9], ,[15] ,[1]
22	Noninvolvement of other parties during design phase	Misinterpretations in construction due to the designer's failure to involve the owner and contractor throughout the design phase.	[8], [13], [15],
23	Modification of original design	Improving the design, which in some cases differs significantly from the initial concept.	[18], [15],
24	Lack of design experience	Design consultant's inexperience especially in designing mega projects.	[16] ,[15] ,[1]
25	Application of inappropriate standards	Designing using the incorrect specifications and standards.	[17], [15],
	Uncontrollable-Factors		
26	Problems or unforeseen Site conditions	Issues related to the site, that aren't initially identified or noticed. Sometimes this is due to poor study conducted.	[16],[8],[9] ,[15] ,[4]
27	Political Instabilities	Change of government and threats that results during election periods.	[16], [4]
28	Very poor weather conditions	Adverse, unstable and unpredictable weather conditions.	[16],[8],[14]
29	Changes in governmental policies	The changes in laws and regulations that directly or indirectly affects a project	[13],[16],[8],[9] ,[15] ,[1] ,[4]
30	Inflations and interest and exchange rates	Describes the effects these changes in monitory value have on projects design change	Expert opinion

Table 2. 30 selected causes of design change in power project

	Power plant		Renewable		Distribution &Transmission	
Controllable factors	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
Owner-Related						
Change of Plans	2.82	18	3.02	20	3.33	3
Technology changes	2.62	28	2.93	24	2.36	30
Conflict between contract documents	3.07	5	3.12	16	2.93	13
Lack of technical knowledge to comprehend and visualize project	2.8	20	3.14	13	2.67	18
Financial problems	3.67	1	3.93	1	3.71	1
Poor project objective definition	3.04	7	3.29	9	3.14	5
Long decision making time	2.93	11	3.33	7	3.21	4
Additional work	2.73	22	3.07	18	3.14	5
Change of designers	2.71	23	2.64	30	3	12
Estimation errors	2.64	26	2.86	26	2.67	18
Ineffective supervision	2.64	26	2.83	27	2.55	26
Contractor-Related						
Equipment and Material failure	2.87	17	3.31	8	2.74	16
Health and Safety considerations	2.93	11	3.21	10	3.1	10
Lack of coordination and communication	3.02	9	2.88	25	2.64	21
Deficient resources in quality and quantity	2.89	14	3.64	2	3.12	8
Inadequate construction experience	2.89	14	2.98	23	2.67	18
Lack of awareness about governmental regulations, statues and their modification	2.93	11	3.14	13	2.52	27
Inadequate pre-construction study and review of design documents	2.89	14	3.38	6	2.64	21
Contractor's desire to improve their financial situation	2.29	30	3	22	2.57	25
Design-Related						
Design complexity	2.82	18	3.07	18	2.71	17
Errors and Omission in design	3.47	2	3.4	4	3.12	8
Noninvolvement of other parties during design phase	3.07	5	3.19	11	2.9	14
Modification of original design	3.16	4	3.1	17	3.05	11
Lack of design experience	2.96	10	3.14	13	2.6	24
Application of inappropriate standards	3.04	7	3.17	12	2.9	14
Uncontrollable-Factors						
Problems or unforeseen Site conditions	3.29	3	3.4	4	3.43	2
Political Instabilities	2.78	21	2.81	28	2.45	29
Very poor weather conditions	2.67	24	2.71	29	2.48	28
Changes in governmental policies	2.6	29	3.02	20	2.62	23
Inflations and interest and exchange rates	2.67	24	3.57	3	3.14	5

Table 3. Rank and Mean score for 30 causes of design change for subdivision

4. Results

The scope of this study is identifying causes of design change that exists in power projects. Information obtained from respondents are translated using analysis of variance, ANOVA in SPSS to determine mean values and establish relationships between causes in subdivisions. The findings in Table 2 revealed that, for power plant subdivision, financial problems, errors and omission in design, problems or unforeseen site conditions, modification of original design, and conflict between contract documents rank top five important causes. For renewable subdivision, the top five important causes are, financial problems, deficient resources in quality and quantity, inflations and interest and exchange rates, errors and omission in design, problems or unforeseen site conditions, inadequate pre-construction study and review of design documents. Also, financial problems, problems or unforeseen site conditions, change of plans, long decision making time, and poor project objective definition are the top five rank important causes for distribution and transmission subdivision.
Furthermore, as illustrated in Figure 1, financial problems, errors and omission in design, problems or unforeseen site conditions and poor project objective definition ranked as common causes in the top 10 causes for all three project types. Finally, the results shows that financial problems attributed to owner-related factor is the most important cause for design change in all subdivisions

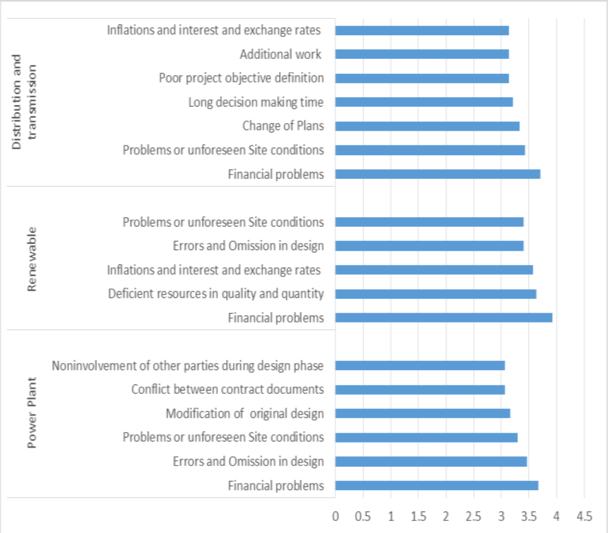

Figure 1. Graphical representation of top 5 important causes ranking for project-types

4. Discussion

The results shows owner-related financial problem as the most important cause of design change for all subdivisions ranking first as shown in table 3. This is the only result that all three subdivisions have in common in terms of rank, clearly demonstrating how important this factor is in the Ghanaian power projects. Expert's comments also indicates that this cause is a predominant issue not only in the power sector but other construction disciplines. Unlike previous studies, owner-related financial concerns are viewed as an important driver of design change, but not the most important cause. Due to the region and the nature of the sector, these modifications may differ. Owner's inability to satisfy contractor's demand financially owing to increasing business and market demands as well as estimation errors places serious pressure on contractors. This type of problem causes the owner to adjust the scope of the project in order to meet the project's financial commitments. In addition, three other factors rank common in the top ten important causes for all subdivisions even though they rank differently. Overall, the major findings is that the viewpoint of each subdivision on important causes for design changes are different according to the mean rank from respondent feedbacks. Variations in findings is as a result of scope and nature of work, projects complexity, the type of contractual agreement and involved stakeholders for each subdivision project.

5. Conclusions

This research is a game changer in Ghana's efforts to address design changes, particularly in the power sector, where there has been limited previous study. Therefore with the findings in this paper, project stakeholders for various sectors in the power industry are able to understand and propose effective design change management strategies to minimize the effects of design change on projects. Furthermore, because Ghana intends to incorporate nuclear energy into its energy mix by building nuclear power plants, the ideas and findings of this study will help to avoid problems that develop as a result of design changes and will enable for successful design change management implementation.

AKNOWLEDGEMENT

This research was supported by the 2021 Research Fund of the KEPCO International Nuclear Graduate School (KINGS), the Republic of Korea.

REFERENCES

[1] A. B. E. Nito, "Article information : Analysis of causes and impact of variation order on educational building project," *J. Small Bus. Enterp. Dev.*, vol. 12, no. 4, pp. 564–578, 2005.
[2] O. Akinradewo, C. Aigbavboa, A. E. Oke, H. Coffie, and B. Data, "POSTGRADUATE RESEARCH CONFERENCE 2019 : Contemporary and Future Directions in the Built Environment," no. February, 2020.

[3] A. A. G. A. Yana, H. A. Rusdhi, and M. A. Wibowo, "Analysis of factors affecting design changes in construction project with Partial Least Square (PLS)," *Procedia Eng.*, vol. 125, pp. 40–45, 2015, doi: 10.1016/j.proeng.2015.11.007.

[4] I. J. Suleiman and V. G. M. Luvara, "Factors Influencing Change of Design of Building Projects during Construction Stage in Dar-es-Salaam Tanzania," *Int. J. Constr. Eng. Manag.*, vol. 5, no. 4, pp. 93–101, 2016, doi: 10.5923/j.ijcem.20160504.01.

[5] Matusala Bassa, "Causes and Effects of Design Change in Building Construction Projects in Three Selected Southern Ethiopia Zones.," *Int. J. Eng. Res.*, vol. V8, no. 12, pp. 757–761, 2020, doi: 10.17577/ijertv8is120213.

[6] A. Alshdiefat and Z. Aziz, "Causes of Change Orders in the Jordanian Construction Industry," *J. Build. Constr. Plan. Res.*, vol. 06, no. 04, pp. 234–250, 2018, doi: 10.4236/jbcpr.2018.64016.

[7] R. O. Asamaoh and K. Offei-Nyako, "Variation Determinants in Building Construction: Ghanaian Professionals Perspective," *J. Constr. Eng. Proj. Manag.*, vol. 3, no. 4, pp. 20–25, 2013, doi: 10.6106/jcepm.2013.3.4.020.

[8] R. U. Halwatura and N. P. N. P. Ranasinghe, "Causes of Variation Orders in Road Construction Projects in Sri Lanka," *ISRN Constr. Eng.*, vol. 2013, pp. 1–7, 2013, doi: 10.1155/2013/381670.

[9] A. Alaryan, A. Elshahat, and M. Dawood, "Causes and Effects of Change Orders on Construction Projects in Kuwait," *J. Eng. Res. Appl. www.ijera.com ISSN*, vol. 4, no. 2, pp. 2248–962201, 2014, [Online]. Available: www.ijera.com.

[10] W. Ibbs, "Construction Change: Likelihood, Severity, and Impact on Productivity," *J. Leg. Aff. Disput. Resolut. Eng. Constr.*, vol. 4, no. 3, pp. 67–73, 2012, doi: 10.1061/(asce)la.1943-4170.0000089.

[11] S. F. Sawyer, "Analysis of Variance: The Fundamental Concepts," *J. Man. Manip. Ther.*, vol. 17, no. 2, pp. 27E-38E, 2009, doi: 10.1179/jmt.2009.17.2.27e.

[12] J. M. Gottman *et al.*, "Predicting Marital Happiness and Stability from Newlywed Interactions Published by : National Council on Family Relations Predicting Marital Happiness and Stability from Newlywed Interactions," *J. Marriage Fam.*, vol. 60, no. 1, pp. 5–22, 1998, doi: 10.1002/job.

[13] M. Staiti, M. Othman, and A. A. M. Jaaron, "Impact of change orders in construction sector in the west bank," *Proc. Int. Conf. Ind. Eng. Oper. Manag.*, vol. 8-10 March, pp. 1690–1698, 2016.

[14] A. R. Khoso, J. S. Khan, R. U. Faiz, and M. A. Akhund, "Assessment of Change Orders Attributes in Preconstruction and Construction Phase," *Civ. Eng. J.*, vol. 5, no. 3, p. 616, 2019, doi: 10.28991/cej-2019-03091273.

[15] M. I. Mohamad, M. A. Nekooie, and A. B. S. Al-Harthy, "Design changes in residential reinforced concrete buildings: The causes, sources, impacts and preventive measures," *J. Constr. Dev. Ctries.*, vol. 17, no. 2, pp. 23–44, 2012.

[16] A. S. For *et al.*, "Space with a font size 28 ERBIL GOVERNORATE FROM THE POINT OF VIEW OF THE Space with a font size 24," vol. 20, no. 05, 2016.

[17] M. Aslam, E. Baffoe-Twum, and F. Saleem, "Design Changes in Construction Projects – Causes and Impact on the Cost," *Civ. Eng. J.*, vol. 5, no. 7, pp. 1647–1655, 2019, doi: 10.28991/cej-2019-03091360.

[18] J. Y. Boon Hui, H. Abdul-Rahman, and W. Chen, "Design Change Dynamics in Building Project: From Literature Review to A Conceptual Framework Formulation," *J. Surv. Constr. Prop.*, vol. 8, no. 1, pp. 13–33, 2017, doi: 10.22452/jscp.vol8no1.2.