Geotechnical Investigations and Implications on the Execution of Building Projects in Nigeria.

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Abstract

This study examined the difference in awareness levels among clients, contractors, and consultants about geotechnical investigation practices in construction projects. It also identified the causes of inadequate geotechnical investigation in building projects and determined its performance impact. A structured questionnaire was administered to 384 randomly selected construction industry professionals in Kwara, Kogi, Niger States, and the Federal Capital Territory (FCT), Abuja, all in the North-central geopolitical zone of Nigeria. A response rate of 62.20% (239 valid responses) was achieved, and the data were analyzed using a combination of descriptive analysis, rank order, and inferential statistics using Microsoft Excel and Statistical Package for the Social Sciences (SPSS). The findings reveal the existence of a heterogeneous practice of geotechnical investigation for building projects among the contracting firms, consulting firms, and client organizations in Nigeria, and the regression model could predict that relationship among geotechnical investigation and identified variables. $Adequate\ Geotechnical\ Investigation = -0.250 + 0.089 * Client\ Awareness - 0.038 * Financial\ Constraint" + 0.387 * Sampling\ Technique + 0.582 * Equipment"$ *Additionally, the impact of the inadequate geotechnical investigation on cost, schedule, and performance of building projects amount to overruns and poor performance.*

Keywords: *Building Projects, Construction Industry, Cost Overrun, Project Performance, Schedule Overrun*

1. Background

The success of most civil engineering projects largely depends on the adequacy of geotechnical investigation of surface and subsurface soil conditions. A poor appreciation and application of geotechnical engineering have been a major concern, being blamed for many engineering and structural failures. These engineering failures relate to the ground conditions and foundations, slopes and infrastructure for road, rail and utilities, and often to extreme and expensive consequences (David *et al*., 2017). Inadequate or insufficient geotechnical investigations leads to inappropriate designs, environmental damage to the site, delays in construction schedules, costly construction modifications, and other related issues (Temple and Stukhart, 1987; Zumrawi, 2014; Žlender and Jelušič, 2016; Neupane, 2016). The stability and durability of civil engineering structures (for instance, buildings, highways, dams, bridges, etc.) are dependent on the stability of soil used for foundation or as construction materials (Laskar and Pal, 2012).

It is inferable from earlier studies on geotechnical investigations (Nwankwoala and Amadi, 2013; Avwenagha *et al*., 2014; Nazir, 2014) that engineers, project managers, and other built environment practitioners use the information acquired from geotechnical investigation to design and effectively manage these projects in order to satisfy the project constraints of time, cost, and quality. The results from the geotechnical investigation are used to determine the strength of the soil and groundwater levels and to propose any geometry of the supporting structures (Nazir, 2014). Although a geotechnical investigation is usually carried out in phases, many scholars highlight the phases involved as preliminary investigation or desk study, detailed investigation, and investigation during construction (Baecher and Christian, 2003; Zumrawi, 2014; Albatal *et al*., 2013; Myburgh, 2018). The initial phase involves carrying out a desk study or acquiring geological information about the region. Myburgh (2018) notes that the desk study involves a detailed review of existing records. After the initial phase, a detailed investigation is carried out to obtain data through in-depth exploration, sampling, measurement, physical examination, laboratory tests, and analyses of both surface and subsurface soils. Although this phase may be regarded as the costliest, it is the most cost-effective phase of the investigation process by reducing the potential for unforeseen ground risks. The investigation during the construction phase mainly aims to enhance previous findings of the preceding phases of the investigation (Myburgh, 2018). This investigation is carried out during earthwork or construction of the foundation; therefore, geotechnical investigations must be conducted and supervised by qualified and experienced professionals to guard against the observation (Charles, 2005).

It has been shown that a link exists between geotechnical analysis and cost overrun in infrastructure projects (Amadi and Higham 2016; Hintze 1994; Temple and Stukhart, 1987). In addition, case histories presented by Kelly *et al*. (2020) demonstrated that the quality and depth of site investigation directly impact actual performance versus predicted performance and hence on the cost and time performance of the project. Attributed risks within the ground amount to high cost and time overruns on construction projects. Sadly, a comprehensive site investigation to address such risks is often ignored as an unnecessary cost (Hytiris *et al*., 2014). Contrarily, Moh (2004) and Nazir (2014) attributed geotechnical failures to inadequacy of standard specifications concerning the scope and quality of site investigation.

The consequences of insufficient information from geotechnical conditions adversely affect both the financial and technical performance of construction projects, resulting in additional costs of construction, operation, or maintenance (Clayton, 2001) and, in worst cases, loss of lives and properties, building collapse, or complete demolition and reconstruction. In addition, inadequate site investigation can lead to overdesign and/or under design. This could have been avoided if a proper site investigation had been conducted. According to Hytiris *et al*. (2014), the cost performance analysis for some selected building projects showed that 44% of cost increases are attributable to inadequate site investigation. This is similar to the outcome presented in Albatal *et al*. (2013), which shows that inadequate geotechnical and site investigation lead to cost overrun by about 64.2%.

The incidence of building collapse has been a reoccurring issue for a considerable period in Nigeria (Ayedun *et al*., 2011, Hamma-Adama and Kouider, 2017). Building collapses are manifestations of failures that are not identified and addressed (Okagbue *et al*., 2018). A failure can be considered as occurring in a component when that component can no longer be relied upon to fulfil its principal functions (Ayininuola and Olalusi, 2004). According to So *et al.* (2008), structural failures may occur at three phases of a building's lifespan: construction, operation, and rebuilding. Hence, failures at any stage may result in potentially fatal accidents for construction workers or end-users, as the case may be. Lawal *et al*. (2017) also argued that buildings give initial symptoms of distresses in the form of defects before they eventually fail. Defects in buildings thus constitute undesirable challenges and threats to users. Olanitori (2011) opined that defects emanate from design errors, manufacturing flaws, defective materials, improper use or installation of materials, lack of adherence to the design, or any mix of the aforementioned causes. Lawal *et al*. (2017) identified active cracks on beams, columns, slabs and walls, improperly sloped roof gutters as building defects. According to their study, the probable causes of these defects were workmanship errors and defective materials.

Islam *et al*. (2021) presented that building professionals frequently experience defects and failures in different structural components, which are essential to a buildings' performance within its service period. Their study revealed that the most severe defects in buildings were footing/column settlement, tilting, cracks (in columns, beams, walls, and slabs), efflorescence, and seepage in walls and slabs. The study also identified improper sub-soil investigation, imperfect structural design, poor quality of materials used, poor workmanship, and excessive live load due to change in service types after construction as the common causes of these defects.

Ayedun *et al*. (2011) empirically ascertained the causes of building failure and collapse from the stakeholders' perspectives. These include poor workmanship by contractors, use of incompetent contractors, faulty construction methodology, non-compliance with standards by contractors, inadequate supervision, structural defects, defective design/structure, and dilapidating structures as the major causes of building collapse in Lagos State. Similarly, through a systematic review of literature, Okagbue *et al*. (2018) harmonized the causes of failures and collapses of buildings in Nigeria. The findings revealed the most common causes as inferior construction materials, geophysical or natural causes, structural defects, inefficient management of construction processes, construction defects, corruption or sharp practices, as well as non-compliance with legal requirements. Hamma-Adama and Kouider (2017) identified substandard reinforcement, structural steel and cement used for foundations, erection of columns, beams and slabs as the main causes of building collapse in Northern Nigeria. Additionally, Fagbenle and Oluwunmi (2010) identified hasty construction, low-quality workmanship, poor supervision, inexperience (use of incompetent hands), ignorance, evasion/ non-compliance with building regulations and non-enforcement of building quality as the major causes of building failures in Northern Nigeria.

Akinradewo *et al*. (2019) concluded from their study that poor financial control on-site, previous contractor experience, contract management, and wrong estimation method were major factors that cause cost overrun in building construction projects. Cost overrun is the difference between the planned or estimated cost and the actual construction cost on completion (Niazi and Painting, 2016). Enshassi and Ayyash (2014), in their study, categorized the factors causing cost overrun in building projects as client-related, project team-related, contractor-related, economic-related, political-related or manpower-related. Similarly, Chulkov *et al*. (2019) grouped the underlying factors into project, contract, client, contractor consultant, workforce and external categories.

The significance of geotechnical investigation cannot be overemphasized as findings would curb project failure drastically. As such, risks would be minimized, and the potential for a safe and economical design would be maximized. A higher likelihood of project completion within time and cost is also realizable (Watts and Davis, n.d.). It is also imperative that project team members, including young and inexperienced practitioners, be accustomed to minimum geotechnical investigation requirements for basic knowledge applicable to any kind of project.

Given the preceding, this paper seeks to examine the difference in awareness level among clients, contractors, and consultants about geotechnical investigation practices in building construction, to identify the causes of inadequate geotechnical investigation on construction projects, and to assess the impact of the inadequate geotechnical investigation on construction project performance.

2. Materials and Method

The study adopted a mixed-method approach, combining both qualitative and quantitative methods. Wisdom and Creswell (2013) note that a mixed-method approach is an emergent methodology of research that systematically integrates both the qualitative and quantitative data within a single programme of study. It enhances an understanding of the contradictions inherent in quantitative and qualitative results and ensures that findings are rooted in participants' experiences (Wisdom and Creswell, 2013). The survey questionnaire was utilized as a data-gathering tool to ascertain respondents' perceptions on some geotechnical investigation related issues. The survey was conducted with a sample size of 384 using the formula for sample size determination proposed by Cochran (1977) (equation 1).

$$n_0 = \frac{Z^2 pq}{e^2} \qquad \text{eqn 1}$$

Where:

e = desired level of precision = 0.05

p = proportion of the population with desired attribute = 0.5

q = 1 – p = 0.5

Z = 1.96 at 95% Confidence level

Questionnaires were administered to Civil Engineers, Geotechnical Engineers, Engineering Geologists, Project Managers, Builders, Architects, Quantity Surveyors, and Surveying & Geo-informatics professionals from client organizations, contracting firms, and consulting firms in North-Central Nigeria (Kwara, Kogi, and Niger States and the Federal Capital Territory (FCT) Abuja). As suggested in earlier works on sampling techniques (Drott, 1969; Emerson, 2015), the participants were randomly selected. The choice of the study areas was influenced by a combination of convenience, proximity, geological nature of the areas, as well as the prevailing socio-economic situation. A combination of descriptive analysis, rank order and inferential statistics were used to present the data. Microsoft Excel and Statistical Package for the Social Sciences (SPSS) were used to analyse the data.

In order to achieve the objectives of this study, five hypotheses were proposed as follows:

$H_0$1: The distribution of geotechnical investigation practice in building construction is not statistically different across categories of organization type

$H_0$2: The distribution of 'designated groups or personnel responsible for geotechnical investigation' is not statistically different across categories of organization type.

$H_0$3: The distribution of 'adherence to the results acquired from a geotechnical investigation in the design and construction of building projects is not statistically different across categories of organization type.

$H_0$4: The distribution of 'sampling technique' is not statistically different across categories of organization type.

$H_0$5: The distribution of 'method of soil observation' is not statistically different across categories of organization type.

The hypotheses would be tested using the Kruskal-Wallis H Test. This is a non-parametric test for determining whether samples originate from the same distribution (Daniel, 1990, Kruskal and Wallis, 1952). The Kruskal-Wallis test's null hypothesis, while assuming that the groups' mean ranks are equal, does not assume that the underlying data are normally distributed (Xia, 2020). Existing works on statistical analysis (Gauthier and Hawley, 2015, Riffenburgh and Gillen, 2006, Hoffman, 2019) suggest that Kruskal-Wallis test statistic determined using an equation similar to equation 2.

$$H=\frac{12}{N(N+1)}\sum_{i=1}^{K}\frac{R_i^2}{n_i}-3(N+1) \quad \text{eqn 2}$$

Where N is the total number, ni is the number in the i-th group, and Ri is the total sum of ranks in the i-th group.

The Kruskal-Wallis H Test would be used to examine differences in awareness levels of the clients, contractors, and consultants about geotechnical investigation practices in building construction. The decision rule is to reject the null hypothesis and accept the alternative hypothesis if the significance value is less than the chosen alpha value (α =.05).

A regression analysis was equally carried out to derive a mathematical model of the relationship between the identified dependent and independent variables (Chatterjee and Simonoff, 2012). The equation model of the study is presented below:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\varepsilon \quad \text{eqn. 3}$$

Where:

"Y=Adequate Geotechnical Investigation"

"β" _"0" "=Constant" ; "β" _"1" 〖"- β" 〗_"6" "=Regression coefficients" ; "X" _"1" "=Client awareness" ;

"X" _"2" "=Financial Constraint" ; "X" _"3" "=Result presentation" ; "X" _"4" "=Supervision" ;

"X" _"5" "=Sampling Techniques" ; "X" _"6" "=Equipment" ; "ε=Stochastic disturbance error term"

3. Analysis of Results and Findings

3.1 Distribution of Respondents

A 62.2% response rate (239 valid responses) was achieved, which is adjudged sufficient to produce a valid and generalizable outcome. Furthermore, the result of the data analysis revealed a good mix in terms of professional affiliation, qualification, experience, and location. Therefore, the outcome is representative and could be generalized to a larger population. The distribution of the respondents according to academic qualification is National Diploma (12 respondents or 15%), Bachelor's degree (130 respondents or 54.4%), Master's degree (76 respondents or 31.8%), and PhD (21 respondents or 8.8%) as shown in Table 1. The distribution according to the professional qualification of respondents showed that 23% (55) of the respondents were Civil engineers, 14.6% (35) were Project managers, and 13.8% (33) were Geotechnical engineers. Other representative professionals include Architecture (12.6%), Surveying and Geo-informatics (12.6%), Quantity Surveyor (11.3%), Engineering Geologist (7.9%), and Builder (4.2%), as shown in Table 2.

Table 1: Highest qualification of respondents

Qualification	Frequency	Percent
ND	12	5
Bachelor's Degree	130	54.4
Master's Degree	76	31.8
PhD	21	8.8
Total	239	100

Table 2: Profession of respondents

Profession	Frequency	Percent
Civil Engineer	55	23
Geotechnical Engineer	33	13.8
Engineering Geologist	19	7.9
Project Manager	35	14.6
Builder	10	4.2
Architect	30	12.6
Quantity Surveyor	27	11.3
Surveying and Geo-informatics	30	12.6
Total	239	100

The result equally revealed that 30.5% (55) of the respondents were in the FCT, 26.8% (64) in Kwara State, 24.3% (58) in Niger State, and 18.4% (44) in Kogi State. About forty-four per cent (107) of the respondents work in contracting firms, while 29.3% (70) were from client organizations, and 25.9% (62) in consulting firms. For the frequency distribution for years of practice experience in building construction, results showed that about 46.4% (111) had at least ten years of practice experience in building construction while the other 53.6% (128) had years of experience ranging between 1-10 years.

3.2 Uniformity in Geotechnical Investigation Practices by Organizations

The summary of the Kruskal-Wallis H Test to examine to determine if a difference in awareness level among clients, contractors, and consultants about geotechnical investigation practices in building construction exists is presented in Table 3. There was no sufficient evidence to support the proposed hypotheses based on the results. Therefore, null hypotheses $H_0 1$, $H_0 2$, and $H_0 3$ were rejected as they had significant values less than the alpha value of.05. The alternate hypotheses accordingly were retained. However, the Kruskal-Wallis H Test summary for sampling technique and methods of soil observation summary shows significant values of .256 and .263, respectively. Therefore, because they are greater than the chosen alpha value (α = .05), we accept the proposed null hypotheses $H_0 4$ and $H_0 5$.

Table 3: Kruskal-Wallis H Test Summary for Hypotheses 1 to 5

S/No	Description Hypothesis	Sig.	Decision
1	$H_0 1$ - The distribution of 'geotechnical investigation practice in building construction is not statistically different across categories of organization type.	.000	Reject the null hypothesis.
2	$H_0 2$ - The distribution of 'designated group or personnel responsible for geotechnical investigation' is not statistically different across categories of organization type.	.000	Reject the null hypothesis.
3	$H_0 3$ - The distribution of 'adherence to the results acquired from a geotechnical investigation in the design and construction of building projects' is not statistically different across categories of organization type.	.000	Reject the null hypothesis.
4	$H_0 4$ - The distribution of 'Sampling technique' is not statistically different across categories of organization type.	.256	Retain the null hypothesis.
5	$H_0 5$ - The distribution of 'Method of Soil Observation' is not statistically different across categories of organization type.	.263	Retain the null hypothesis.

3.3 Causes of inadequate geotechnical investigation

Causes of the inadequate geotechnical investigation were ranked and presented in Table 4. According to respondents' assessments, the result shows that 'Client Awareness', 'Equipment', 'Sampling technique', and 'Financial Constraints' are the major causes of inadequate geotechnical investigation in building projects. The result also reveals that 'Lack of geotechnical expertise' and 'Lack of

Table 4: Causes of inadequate geotechnical investigation in building projects

	(1)	(2)	(3)	(4)	(5)	Mean	Std. Dev.	Rank	*p*-value	R
Client Awareness	0	6	14	55	164	4.59	.710	1	.000	.494
Equipment	0	0	33	53	153	4.50	.727	2	.000	.902
Sampling technique	20	0	13	42	164	4.38	1.164	3	.000	.894
Financial constraint	0	36	38	25	140	4.13	1.156	4	.004	-.185
Supervision	20	2	26	102	89	4.00	1.128	5	.017	.115
Result presentation	20	0	46	117	56	3.79	1.068	6	.000	.295
Time constraint	0	10	88	94	47	3.74	.818	7	.003	.822
Lack of geotechnical expertise	20	30	58	92	39	3.46	1.222	8	.005	.874
Lack of integration	33	10	48	109	39	3.42	1.153	9	.000	.956

integration' ranked lowest with mean values 3.46 and 3.42 respectively.

3.4 Implications of inadequate geotechnical investigation on building projects

The study sought to establish the perception of critical building project stakeholders about the implications of inadequate geotechnical investigation on cost, schedule, and performance of building projects. Concerning cost, the results revealed that inadequate geotechnical investigation has a significant impact on the cost of building projects (Figure 1).

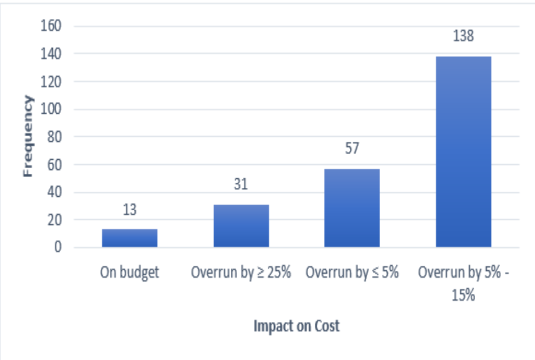

Figure 1: Implication on Cost

Although about 5% of the respondents believed that the project would remain within the budget even with geotechnical related changes, a larger proportion of the respondents believed that it would lead to cost overrun. About 58% of the respondents estimated that the cost overrun could be between 5% and 15%. Although another 24% of the respondents agreed that it could lead to a cost overrun, they believed the cost overrun is usually more than 5%, while 13% agreed that cost overrun is usually over 25% of the project cost.

It is equally noticeable from the study results that geotechnical related changes adversely affect the schedule of building projects (Figure 2).

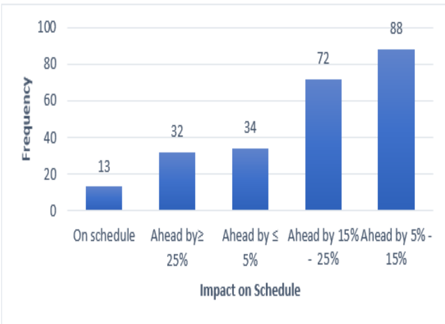

Figure 2: Impact on Schedule

About sixty-seven per cent of the respondents agreed that geotechnical related changes caused schedule overrun ranging between 5% and 25%. Additionally, thirteen per cent of the respondents felt that schedule overrun due to geotechnical related changes could be greater than 25%, while fourteen per cent of the respondents agreed that schedule overrun is usually less than 5%.

3.5 Implications on Performance of Building Projects

Table 5 presents the respondents' views about the implications of inadequate geotechnical investigation on the performance of building projects. The variable, 'Settlement', ranked first with a mean score of 4.49, while 'reduction in bearing capacity due to ground failures' ranked second with a mean score of 4.50, and 'cracks on structural elements (beam, slab, column)' ranked third with mean score 4.48. Furthermore, 'kinematic forces acting on deep foundations due to shear deformation of soils and overturning moments imposed on the foundation from the superstructures' ranked fourth with mean scores 4.46; 'collapsed foundations and tilting of buildings' ranked sixth with a mean score of 4.41, while 'cracks on walls' with a mean score of 4.19 was the least ranked. These indicate the extent to which inadequate geotechnical investigation adversely impacts building projects. Hence, the severity could be as high as settlement of the structure, reduction in bearing capacity, or collapsed foundations. More so, these defects could lead to the loss of lives and properties.

Multiple regression analysis was conducted to study the relationship between adequate geotechnical investigations and the identified predictors. An initial analysis showed

Table 5: Impact of geotechnical investigation related defects on building project performance

	(1)	(2)	(3)	(4)	(5)	**Mean**	**Std. Dev.**	**Rank**	***p*-value**	**R**
Settlement	0	20	13	13	193	4.59	.926	1	.000	.659
Reduction in bearing capacity due to ground failures	0	0	33	53	153	4.50	.727	2	.000	.708
Cracks on structural elements (beam, slab, column)	0	0	33	59	147	4.48	.727	3	.000	.403
Kinematic forces acting on deep foundations due to shear deformation of soils	0	20	13	42	164	4.46	.929	4	.000	.735
Overturning moments imposed on the foundation from the superstructures	0	20	13	43	163	4.46	.929	4	.000	.767
Collapsed foundations	0	20	13	54	152	4.41	.926	6	.000	.741
Tilting of buildings	0	20	13	56	150	4.41	.925	6	.000	.839
Collapsing soils/liquefaction	20	0	13	42	164	4.38	1.164	8	.000	.599
Cracks on wall	0	36	36	13	154	4.19	1.169	9	.000	-.079

high multicollinearity among the independent variables. Hence, the final regression analysis excluded three independent variables (time constraint, lack of geotechnical expertise). Table 6 summarises the descriptive statistics and analysis of results and shows a multiple correlation coefficient (R) value

Table 6: Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.947a	.897	.894	.301	1.749

[b]. Dependent Variable: Y

of 0.947) of the six independent variables with the dependent variable as presented. The adjusted R-Square value of .894 indicates that 89.4% of the variance in the dependent variable is explainable by the six independent variables.

In order to examine the desirability of the regression model, independent variables with p-values greater than .05 were removed from the model.

The model of the relationship between the dependent variable (adequate geotechnical investigation) and the independent variables is represented by:

$$Y = -.250 + .089X_1 - .038X_2 + .387X_5 + .582X_6 \quad \text{eqn. 4}$$

Where Y = Adequate Geotechnical Investigation,

X1 = Client Awareness, X2 = Financial Constraint, X5 = Sampling technique,

X6 = Equipment

4. Discussion

The findings from the study revealed a disparity in the perception level of the three groups (clients, contractors, and

Table 7: Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	T	Sig.	Tolerance	VIF
(Constant)	-.250	.181		-1.379	.169		
Client awareness	.089	.033	.068	2.695	.008	.697	1.436
Financial constraint	-.038	.017	-.048	-2.222	.027	.959	1.043
Error in result presentation	.013	.036	.015	.358	.721	.263	3.801
Supervision	.011	.033	.013	.329	.743	.281	3.558
Sampling	.387	.031	.487	12.430	.000	.289	3.456
Equipment	.582	.052	.457	11.094	.000	.262	3.818

a. Dependent Variable: Y

consultants) about the practice,

designation of responsibility, and adherence to results of a geotechnical investigation in building projects. However, there is no statistical evidence of a significant difference in sampling technique and (soil) sample observation methods in building projects among the groups. The study also identified the causes of inadequate geotechnical investigation in building projects. The findings further revealed that identified variables are statistically significant, with *p*-values ranging from 0.00 to 0.017 and correlation coefficient 'r' ranging from -0.185 to 0.956. This result implies that most clients, especially residential buildings, have very low awareness of the importance of conducting a geotechnical investigation.

Furthermore, the emergence of 'equipment' as a major cause of inadequate geotechnical investigation in building projects implies that the lack of necessary equipment and machinery significantly affects the adequacy of the geotechnical investigation. Furthermore, the results indicate a possible lack of technical know-how or understanding of geotechnical investigation sampling techniques adopted in building projects, given its high mean score. It is also evident that there is usually no budget for geotechnical investigation or insignificant allocated cost. Overall, the trend of the presented result revealed that little or no attention is given to geotechnical investigation in building projects, especially in residential projects.

The variable 'client awareness' with a statistically significant value of .008 (*p*-value < .05) and an unstandardized coefficient .089 indicates that every unit change in client awareness would cause a 0.089 improvement in geotechnical investigation. Similarly, a statistically significant value of .027 (*p*-value < .05) and coefficient value of -.038 for financial constraint implies that a unit increase in budget provision for geotechnical investigation would cause an inadequacy to the geotechnical investigation. The sampling technique used also has a statistically significant value of .000 and a coefficient value of .387, which implies that the variable improves geotechnical investigation by .387. At the same time, a unit increase in equipment would cause an increment of .582 in the adequacy of the geotechnical investigation. On the contrary, result presentation and supervision are not statistically significant with a *p*-value > .05. This implies that these independent variables have no significant impact on the dependent variable. The outcome of this is in line with the conclusion drawn in earlier studies that insufficient geotechnical investigation is one of the first sources of projects' delays, disputes, claims, and projects' cost overruns and that the intended savings, due to conducting inadequate site investigations, lead to cost overrun by 64.2% of the project cost (Albatal *et al*., 2013; Albatal, 2013; Neupane 2016; Žlender & Jelušič 2016).

5. Conclusion and Recommendation

The study concludes that there is a heterogeneous practice of geotechnical investigation in building projects among the contracting firms, consulting firms, and client organizations in Nigeria. The major causes of inadequate geotechnical investigation in buildings are client awareness, equipment, sampling technique, and financial constraint. The study also developed a regression model to show the relationship between these causes and adequate geotechnical investigation. Additionally, based on findings, the study concludes that the inadequate geotechnical investigation impact cost, schedule, and performance of building projects adversely through overruns and poor performance.

Based on the findings and conclusion of this study, the following is recommended;

- Government policies to enforce the detailed and standard practice of geotechnical investigation in building projects
- Clear presentation of investigation results for easy interpretation
- Adequate sampling technique
- Provision of adequate budget to explore subsurface conditions.
- Retention of suitably qualified and experienced design consultants to investigate, evaluate potential risks, prepare drawings, specifications and a geotechnical baseline report consistent with the risks.
- Allocation of sufficient time and financial resources to prepare a detailed geotechnical investigation consistent with other design documents.

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