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IMPACT OF CLIMATE VARIABILITY ON CONSTRUCTION PROJECT ACTIVITIES IN SOUTH-SOUTH, NIGERIA

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ABSTRACT

Purpose: Climate variability in the South-South, Nigeria is a significant concern due to the region's vulnerability to extreme weather events such as heavy rainfall, flooding, and high temperatures. The region, being prone to extreme weather events, is vulnerable to disruption of construction activities and delayed project completion. The motivation of this study is to determine the impact of climate variability on construction project activities in the execution phase in the study area.

Design/methodology/approach: This study assessed the drivers of climate variability in the study area, the extent of the impact of climate variability on construction activities, and determined the critical construction activities impacted by climate variability. Questionnaire survey was administered on proportionately stratified random sample of construction professionals in the study area. The derived data were subjected to both descriptive and statistical analyses using Mean Score, Relative Extent of Impact, and inter-rater agreement to spot the critical construction activities impacted by climate variability. Kendall's Concordance Coefficient was used to test the study’s hypotheses.

Findings: Findings revealed that gas flaring from oil companies, solar radiation, topography, and deforestation are the highest contributors to climate variability in the study area, as perceived by the respondents. Excavation of septic tank and soak-away pit; laterite filling to make up level, and placement of in-situ concrete in foundation footing, ranked in the first three positions as being impacted by rainfall. Excavation of trench for foundation; plain in-situ concrete in floor bed as oversite; and application of paint on external wall ranked in the first three positions as being impacted by temperature. Kendall's coefficients of concordance (W) were 0.89, 0.91, 0.73, and 0.86 for rainfall, temperature, humidity and wind speed respectively, revealing either substantial or perfect agreement among the respondents about extent of impact of climate variability on construction activities.

Research limitations/Implications: The limitations include the use of three States to represent South-South region and the construction processes examined are limited to Building construction project. The contribution to knowledge is that this study established the critical construction activities prone to impact of climate variability in the execution phase.

Practical implications: Managers of construction sites should plan the critical construction activities prone to impact of climate variability as derived by this study against catastrophic impact.

Originality/value: The study revealed that rainfall and temperature significantly impact construction project activities in the study area. Inversely, no construction activity is found to be significantly impacted by humidity and wind.

Keywords: Climate variability; construction activities, critical; impact; South-South, Nigeria

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1. INTRODUCTION

Climate variability in the South-South region of Nigeria is a significant concern due to the region's vulnerability to extreme weather events such as heavy rainfall, flooding, and high temperatures. The region's coastal location and low-lying areas make it particularly susceptible to the impacts of sea level rise and storm surges. The region is home to many important economic activities such as oil and gas production, agriculture, and fishing, with associated construction project facilities to support the economic buoyancy of the region. Climate change and variability have the potential to disrupt these activities and cause significant economic losses. Bennett (1991) established that the environment interferes with the planned progress of construction projects. The less predictable the environment and the greater its potential effects, the more it must be taken into account in managing the development of construction projects.

In a similar vein, construction projects in Nigeria, particularly in the South-South region, are facing increasing challenges due to the impacts of climate variability. The region, being prone to extreme weather events, is vulnerable to disruption of construction activities and delayed project completion (Adewuyi *et al*., 2014). Climate change and variability can increase the frequency and severity of natural disasters, leading to damage to infrastructure and equipment, and further delays to construction projects. With the construction industry tied to most sectors that focus on climate warming initiatives, including transportation, power generation, residential and commercial buildings, manufacturing, mining, forestry, and waste management, experts maintain that the knowledge about short-term weather and long-term climate variability is essential to adequately design and successfully management of construction projects (Olanrewaju *et al*., 2020; El-Sawalhi & Mahdi, 2015). This is especially so in developing countries, including Nigeria. According to Ezeabasili and Okonkwo (2013) decisions made about building and design, especially about infrastructure, have repercussions far into the future. Climate variability affects the built environment by increasing wear on technical infrastructure and the external walls of the buildings and by increasing the risk of flooding in certain areas (Ezeabasili & Okonkwo, 2013). The potential risks of inclement weather and climate conditions also influence planning and project completion timelines (Schuldt et al., 2021). Construction projects that require dry conditions, such as laying roads or foundations, may be delayed indefinitely until the weather subsides. Many studies that semi-quantitatively considered the effects of weather on weather-sensitive construction activities (e. g. Thorpe & Karan, 2008; Ballesteros-Pérez, 2015) focused on the impact of weather or climatic effects on construction activities as related to construction workforce, thereby neglecting the impact on the construction processes per se. Some other previous studies emphasized weather effects on construction activities either as a delay factor causing time overrun due to stoppage of construction activities (Ballesteros-Pérez *et al*., 2015) or productivity factor leading to protracted project duration (Al Refaie *et al*., 2020; Senouci, Al-Abbasi & Eldin, 2018; Usukhbayar & Choi, 2018; Ueno *et al*., 2018). It has therefore become necessary to assess the impact of climate variability on critical construction activities, specifically at execution stage, which are weather-vulnerable.

Climate variability has a direct impact on the cost and quality of construction projects (Schuldt *et al*., 2021). For example, heavy rainfall can lead to soil erosion and landslides, which can increase the cost of construction and reduce the durability of ongoing project activities. High temperatures can cause materials to degrade and workers to experience heat stress, resulting in decreased productivity and quality of work (Al Refaie *et al*., 2020). Climate variability can affect construction projects directly through weather and climate, but can also generate indirect impacts such as site programming, delay, extra expense, worker’s safety, material cost, and delivery (Camilleri *et al*., 2001). There is overwhelming evidence that climate variability has created threats thus, project managers are faced with a challenge and should understand b the influence that climate variability could have on construction projects (Ede *et al*., 2014; Marzouk & Hamdy, 2013; Parry *et al*., 2007).

Moreover, Nigeria is one of the most populous countries in Africa with a population of over 200 million people, and a high rate of urbanization, which puts a lot of pressure on the construction industry to build more housing and infrastructure to meet the demands of a growing population. This reinforces the need for the country’s construction industry, as an important sector, to be resilient to the impacts of climate variability to avoid delays and cost overruns in project delivery. Given the significance of the construction industry in Nigeria and the potential impacts of climate variability on project activities, there is a need for a study to investigate the specific challenges and risks faced by construction projects in the South-South region. There are limited citations of this kind of study in the South-South, hence, this study is set to fill the gap.

1.1. Objectives of the Study

This study is set address the following objectives:

(i) assess the drivers of climate variability in South-South, Nigeria;

(ii) determine the extent of the impact of climate variability on construction activities in the study area;

(iii) determine the critical construction activities impacted by climate variability in the study area.

The study intends to elicit the understanding of construction professionals on the issue of climate variability. Secondly, to explicate the expostulations or threats confronting the professionals on site regarding climate variability. Furthermore, to pinpoint construction activities with greater threats during the execution stage regarding climate variability in the study area.

1.2. Research Hypotheses

Two hypotheses guided the study namely:

H_{O1}: There is no significant agreement in the perceptions of the respondents about the drivers of climate variability among the States in the study area.

H_{O2}: There is no significant agreement in the perceptions of the respondents about the extent of climate variability impact on construction project activities among the States in the study area.

2. LITERATURE REVIEW

2.1. Overview of Climate variability

Climate variability poses a serious challenge to social and economic development. Developing countries like Nigeria are particularly vulnerable because their economies are generally more dependent on climate-sensitive natural resources, and they are less able to cope with the impacts of climate variability (Tunji-Olayeni *et al*., 2019). Climate variability is the result of changes in features of weather conditions, such as temperature, wind patterns, precipitation, and relative humidity. Both natural and artificial factors contribute to climate variability but more by anthropogenic factors or human-induced activities like burning of fossil fuel, bush burning, deforestation, and overgrazing (National Research Council, 2008). Thus, the study of Nguyen *et al.* (2010) classified seven factors that usually cause disputes between the contractor and the contracting authority in projects that suffer delays including adverse weather conditions. The seven factors include the definition of normal weather, weather thresholds, the type of work, the number of lingering days, criteria for lost days, the lost days equivalent due to lost productivity, and the number of work days lost versus the number of calendar days lost. However, the same authors claimed that future research may provide an appropriate mechanism for analysing equivalent lost days to account for lost productivity.

There are extant literatures which reported several weather effects on labour's productivity (Al Refaie *et al*., 2020; Senouci, Al-Abbasi & Eldin, 2018; Usukhbayar & Choi, 2018; Ueno *et al*., 2018; Nguyen *et al*., 2010). Such weather effects include bad weather time or paid time, reduced productivity because of long time working, repeated work resulting from frost ice, wind, rain, or the need to correct poor-quality workmanship, absence, reported lateness of labours due to bad weather, reduced working schedule, or shortened work weeks that occur during winter months and result in a loss of momentum. Moselhi *et al*. (1997) reported that weather conditions can have an adverse impact on the duration and cost of construction activities. They also reported that the productivity loss due to the impact of weather on construction activities can be either partial or complete. A partial loss is generally attributed to reduced labour productivity while a complete loss is ascribed to a work stoppage that interrupts the construction activities. The authors presented an automated decision support system, named "weather", for estimating the combined effect of reduced labour productivity, and work stoppage caused by adverse weather conditions on construction sites. The system provides estimates of construction productivity, activity durations, and weather patterns that facilitate the application of risk analysis in planning and scheduling. Schuldt *et al*. (2021) examined weather-related construction delays in a changing climate for construction projects and how they can be resolved. El-Rayes and Moselhi (2001) developed a decision support system for quantifying the impact of rainfall on the productivity and duration of highway construction operations. Moselhi and Khan (2012) analysed and ranked the parameters that affect job-site daily labour productivity to help job-site personnel in planning and comparing their daily targets and to fine-tune their resource allocations according to the daily situation.

2.2. Drivers of Climate variability

The main sources of climate variability in Nigeria are as a result of bush burning, deforestation, desertification, firewood burning, exhaust pipes, chimneys, gas flaring and urbanization. In Nigeria, it is the domestic, agricultural, and industrial wastes that contribute majorly to climate variability due to industrialization. The developed countries contribute about 97% of the greenhouse gases emission, while the undeveloped countries contribute the remaining 3% (Gana and Aliyu, 2015). Olanrewaju *et al*. (2020) identified carbon dioxide emission from fossil fuel, burning, and power plants as the sources of climate variability. Man’s increasing addiction to electricity has led to establishment of several coal burning power plants which release enormous amounts of carbon dioxide into the atmosphere. The U.S. Environmental Protection Agency (USEPA, 2023) noted that 31% of U.S. carbon dioxide emissions come from electricity production, and burning coal accounts for 93% of emissions from the electric utility industry and carbon dioxide emission from burning gasoline for transportation. With the increasing demand for modern means of transportation and distribution of globally sourced goods, automobiles are increasing in number yearly. For instance, USEPA (2023) noted that about 33% of the emissions emanate from automobiles. For developing countries like Nigeria with a very high population figure, the demand for both new and used cars and consumer goods keeps increasing. This translates to increasing use of fossil fuels for transportation and manufacturing, often without sourcing for alternative energy resources and consequently increasing carbon dioxide concentration in the environment, methane emissions from animals, agriculture, and from Arctic seabed. When organic matter is broken down by bacteria under oxygen-deficient conditions (anaerobic decomposition) as in rice paddies, methane is produced. A similar process takes place in the intestines of herbivorous animals, and with the increase in livestock production, the levels of methane released into the atmosphere is increasing. Also, methane from methane clathrate (a compound containing large amounts of methane trapped in the crystal structure of ice) increases the rate of global warming significantly, as methane escapes from the Arctic seabed (Nwona, 2013). Rapid deforestation for agricultural, commercial and industrial purposes: Man’s quest for urbanization, industrialization as well as production of food crops has led to increasing deforestation in the tropics. Forests remove and store carbon dioxide from the atmosphere. Deforestation releases large amounts of carbon, as well as reduces the amount of carbon capture on the planet. Increase in usage of chemical fertilizers on croplands. In recent times, due to rapid population growth, especially in the underdeveloped nations, there is increasing demand for food and higher crop yields. This has led to more use of chemical fertilizers than animal manure. It has been established that nitrogen oxides have up to 300 times more heat-trapping capacity per unit of volume than carbon dioxide. Also, the run-off of excess fertilizers creates ‘dead zones’ in our oceans. In addition to these effects, high nitrate levels in ground water due to over-fertilization calls for human health concern.

The carbon dioxide (CO_2) emissions from human activities come basically from combustion of carbon-based fuels such as wood, coal, oil and natural gas. The atmospheric concentrations of greenhouse gases are determined by the equilibrium between sources of emission of the gas (biogeographical processes and anthropogenic processes) and sinks (process of removal of the gas from the atmosphere by conversion to a different chemical compound).

2.3. Climate Variability Impact on Construction Activities

The effects of climate variability on construction projects need to be taken into consideration in all aspects of construction from land use planning to the positioning, construction, and life-cycle management of buildings and other infrastructural facilities for human uses and comfort (Yuvan & Murali, 2020). Clever infrastructural planning can counteract some of the negative effects of climate variability and also create attractive built environments. This in fact, is the tenets of environmental sustainability (Ezeabasili & Okonkwo, 2013). It is noted that on-site construction of buildings equally has a relatively low impact emission. It is usually influenced by choice of building materials, construction techniques and modes or distance of transportation of materials deployed to the construction sites (Yusof and Iranmanesh, 2017). The effect of climate variability is also felt during maintenance of buildings due to significant energy use, especially heating and lightning. Climate variability is also likely to increase the change of property development and the need for property maintenance than to decrease them, especially the external surfaces of buildings, which will suffer increasingly from wet and winding conditions as a result of climate variability. This can lead to the faster deterioration of external surfaces of buildings, which will require more regular maintenance in the future. The extreme weather conditions increase erosion and the cost of construction (Gana and Aliyu, 2015).

With the increasing occurrence of climate variability related hazards and disasters, substantial damage to residential and commercial structures is expected. In this regard, flooding is one of the costliest and destructive natural hazards. Flood inundation causes water to sink inside building foundations and this can lead to foundation settlement and softening which could sooner or later result in building collapse. A building may remain intact and stable on the outer surface, while the foundation materials are gradually and severely being damaged. The velocity of flood may erode the building's foundation or the soils under the foundation. This leads to total collapse. Buildings can be washed away due to forceful impact of the water under high velocity. This occurs when light weight houses are not securely anchored or braced. Damages caused by debris can be very scaring as massive floating objects like trees and materials from other collapsed houses may have impact significant enough to cause severe damage to standing buildings. As the effects of climate variability increases, intense wind trust will bow off roofs and building roofing sheets will deteriorate faster due to the effect of intense sun and rainfall acting on them. This may require more maintenance and repairs as a result of damages. In higher temperatures concrete durability deteriorate as cement sets more quickly. Concrete is weaker if it dries too quickly and it will lack durability to corrosion, frost damage, sulphate attack and alkali-silica reaction. Therefore, increasing temperature rise is likely to exacerbate concrete durability problems (Yuvan & Murali, 2020). Additionally, when concrete reacts with atmospheric CO_2, cracking ensures. This process can be accelerated with the increasing CO_2 concentrations in the atmosphere. However, it has been suggested that some measures can be introduced to curb most of these adverse effects during the execution phase, such as covering the concrete with plastic sheets during strong wind or mixing additives with the concrete when concrete is being poured or cured (Ballesteros-Pérez, 2015).

The commencement, continuing and stoppage of outdoor construction activities depend on weather conditions. It has been noted that earthmoving works, such as excavations and landfilling, are affected by rainfall because rainfall hampers performance and raises soil humidity when compacting and frozen soils (Ballesteros-Pérez, 2015; Shahin *et al*., 2011, 2014). Marzouk and Hamdy (2013) studied weather effect on formwork shuttering and removal operations with reference to the level of rainfall and temperature. Steel elements for reinforcing concrete have been reported of being affected by electric storms.

3. METHODOLOGY

The study was conducted using survey research design to obtain the opinion of construction professionals on the impact of climate variability on construction project activities. The three States selected to represent the South-South region were partly based on convenience and partly due to dissimilarity of cultural background and language which naturally stratify the region into three. For instance, Akwa Ibom and Cross Rivers States have similar language and culture which associate the duo but distinctively differentiate them from the other States in the region. In similar view, Rivers and Bayelsa States equally have similar cultural background, and so do Edo and Delta States. Hence, one State each was selected in the three groupings which are Akwa Ibom, Delta and Rivers States. The population size was drawn from the directories of construction professionals in the study area. The population considered for the study was the registered construction professionals, vis-a-vis Architects, Builders, Engineers (Civil, Structural and Services) and Quantity Surveyors.

The study adopted stratified random sampling method which is a method under the probability sampling techniques. This is because the study used a segment (South-South) of the country's construction professionals' population and secondly, because only registered professionals were used. Additionally, the population for the study are distinctively stratified into the various sampled States in South-South of Nigeria. The technique was adopted to enable the comparison of the responses of the various group of professionals among the sampled States for possibility of significant variation in the perceptions of the respondents from different States. According to Fellows and Liu (2008), stratified sampling is appropriate where the population occurs in 'distinct' groups or strata. The sample sizes of each of the group of professionals represent the number of respondents on which the questionnaires were administered. In order to carry out the process of stratified random sampling, the population of professional's affiliation were sourced from their respective State chapters' offices and used in the process of selecting the respondents. The breakdown of the population and sample size, relative to each group of professionals, for each of the selected States in the South-South is shown in Table 1.

Table 1: Sample size of Each Component of the Population Frame

Registered Professionals	**Akwa Ibom**			**Delta**			**Rivers**		
	N	**n_1**	**n_i**	**N**	**n_2**	**n_i**	**N**	**n_3**	**n_i**
Architects	63		41	66		42	95		52
Builders	42		27	45		29	36		20
Engineers	70	146	45	80	150	51	126	186	68
Quantity Surveyors	53		34	48		31	88		48
Total	**228**		**147**	**239**		**153**	**345**		**188**

n_1, n_2 and n_3 are the stratified sample size based on State;

n_i is the stratified sample size based on profession.

In the determination of sample size, the Taro Yamane formula was applied which yielded a total population of four hundred and eight-two (i. e. 146 + 150 + 186 = 482) professionals, using the expression in Equation 1, which are distributed across the three selected States of Akwa Ibom, Delta and Rivers.

$$n = \frac{N}{1 + N(e)^2} \qquad \ldots eqn. 1$$

where:

n is the sample size;

N is the finite population;

e is the level of significance, and 1 is unity.

According to Adewuyi and Umoren (2020), for all significant sub-population and precision to be captured, the proportionate type of stratified random sampling which is the type described in Taherdoost (2016) was adopted based on the expression in Equation 2 for stratifying the sample size into their respective professions in the respective State. The result further increased the sample size slightly to four hundred and eight-eight (i. e. 147 + 153 + 188 = 488).

$$n_i = \frac{nS}{N} \qquad \dots eqn. 2$$

where:

n_i is the sample size in each State;

n is the total sample size derive from Equation 1;

S is the corresponding population of professional in the respective State;

N is the total finite population in each State.

The questionnaire was segmented into two parts (sections A and B). Section A elicited information about the respondent's profile, such as the gender, age, marital status, academic qualifications and professional affiliation, years of experience, to enhance the reliability of the derived data. Section B sourced data on the specific purpose of the study. Five-point Likert scale ratings of 1 to 5 were assigned to the respondent's ratings of the variables, with 1 and 5 interpreted as lowest and highest point, respectively. The criterion-related reliability test of the questionnaire was measured using Cronbach's alpha.

The responses to the questionnaire survey were subjected to both descriptive and statistical analyses using Mean Score (MS), and Relative Extent of Impact (REI). The data mean score (MS) was employed to analyse the data collected for establishing the respondents' knowledgebase of drivers of climate variability, using the expression in Equation 3, which was adopted from Adewuyi and Ujene (2019) with 1 representing the lowest level of effect and 5 representing the highest level. Relative Extent of Impact (REI) analysis was pattern after Relative Importance Index (RII) such that the same expression was adopted for the duo as presented in Equation 4. Hence, REI was used to analyse the impact of climate variability on construction activities.

$$MS = \frac{\sum_{j=1}^{5} W_i X_i}{\sum_{j=1}^{5} X_i}, \qquad (1 \leq MS \leq 5) \qquad \dots eqn. 3$$

where:

Wi is the rating given to each factor by the respondents ranging from 1 to 5, with 1 representing 'not significant' and 5 representing 'extremely significant';

Xi is the level of scoring, and

i is the order number of respondents.

$$Relative\ Extent\ of\ Impact\ (REI)\ \boldsymbol{OR}\ Relative\ Importance\ Index\ (RII) = \frac{\sum W}{A * N} \qquad \dots eqn. 4$$

where:

W is the weight given to each factor by the respondents and ranges from 1 to 5;

A is the highest weight = 5; and

N is the total number of respondents.

Based on five-point Likert scale adopted, a construct is deemed significant if it had a mean score value of 3.00 where the analysis was based on mean score computation such that (1+2+3+4+5)/5 = 3.00. Similarly, a cut-off points of 0.60 was utilised for significant REI or RII value. The cut-off was computed by summing the weights and dividing by the total number of weighting items and highest weight respectively: (1+2+3+4+5)/5/5 = 0.60. Thus, an attribute that have REI or RII that are higher than 0.60 are defined as being significant, those with RII equal to 0.60 are moderate, while those less than 0.60 are insignificant. This approach, adopted from Umoren, Adewuyi and Otali (2019), is with the expectation that the use of 0.60 as reference value will effectively cover only important variables in terms of their influence.

To determine the critical construction activities impacted by climate variability, the analysis was carried out using inter-rater agreement (IRA) scoring, as indicated in Equation 5. Estimates of IRA were used mainly to verify whether rating provided by a respondent is interchangeable or equivalent in complete terms, meaning that IRA is a perfectly reasonable technique for estimating ratters' similarity. IRA represented by **RWG** (rating weighted agreement) was calculated using Equations 5 and 6 as presented by LeBreton and Senter (2008):

$$RWG = 1 - \frac{S_x^2}{\sigma_E^2} \qquad \dots\ eqn\ 5$$

where:

S_x^2 = the observed variance on the variable X;

σ_E^2 = the variance expected when there is a complete lack of agreement among the judges; and

$$\sigma_E^2 = \frac{A^2 - 1}{12} \qquad \dots eqn. 6$$

where:

A = number of response option in the scale; and S_x^2= the observed variance.

Inter-rater analysis is interpreted based on LeBreton and Senter (2008) which denoted 0.00 - 0.30 = lack of agreement; 0.31 - 0.50 = weak agreement; 0.51 - 0.70 = moderate agreement; 0.71 - 0.90 = strong agreement; and 0.91 - 1.00 = very strong agreement. The IRA is different from other critical index parameters in exploring consensus using the variance in respondents' judgment rather than mean score seen in others.

Kendall's Concordance Coefficient, W, is a measure of agreement between numerous judges who have rank-ordered several entities. It is the ratio of the total rank variability for the ranked entities to the maximum feasible total rank variability; a low ratio indicates that the judges disagree.

Kendall's coefficient values can range from 0 to 1. The higher the value of Kendall's, the stronger the association. Usually, Kendall's coefficients of 0.9 or higher are considered very good. A high or significant Kendall's coefficient means that the appraisers are applying essentially the same standard when assessing the samples. The rules adopted is such that $0.00 \leq w < 0.20$ represents slight agreement; $0.20 \leq w < 0.40$ is fair agreement; $0.40 \leq w < 0.60$ is moderate agreement; $0.60 \leq w < 0.80$ is substantial agreement; and $w \geq 0.80$ is almost perfect agreement (Landis & Koch, 1977).

4. PRESENTATIONAND DISCUSSION OF RESULTS

4.1 Demographic Attributes of Respondents

The responses from the usable questionnaire survey were analysed with descriptive and statistical tools. Four hundred and ninety questionnaires were distributed but three hundred and twenty-three were retrieved. Among the retrieved questionnaires, fifteen were unusable because of incomplete responses to substantial number of the questions on them. Consequently, three hundred and eight usable questionnaires, representing about sixty-three percent (63.11%), were analysed in this study. The response rate is deemed acceptable based on the submission of Fincham (2008) that an approximate of 60% response rate should be anticipated in survey studies in the twenty-first century. The descriptive analysis of the respondents' demographic distributions is presented in Figure 1.

Figure 1 shows the gender distribution of the respondents of the study. The percentages of the respondents who are male are 77.3% and female being 22.7% revealing that the construction industry in the study area is dominated by male. The age of the respondents was classified into three: non-active working adolescent (Below 18 years); vibrantly and active working adult (18 – 60 years) and due-for-retirement adult (Above 60 years). Figure 1 shows that none of the respondents is aged less than 18; while 97.7% of the respondents are within the vibrantly and active adults with just 2.3% being above 60 years. This implies that the respondents are matured enough to give creditable and reliable responses to the questions. Similarly, 38.3% are singles adults while 61.7% are married (including widows) adults, indicating that majority of the respondents are matured and responsible adults.

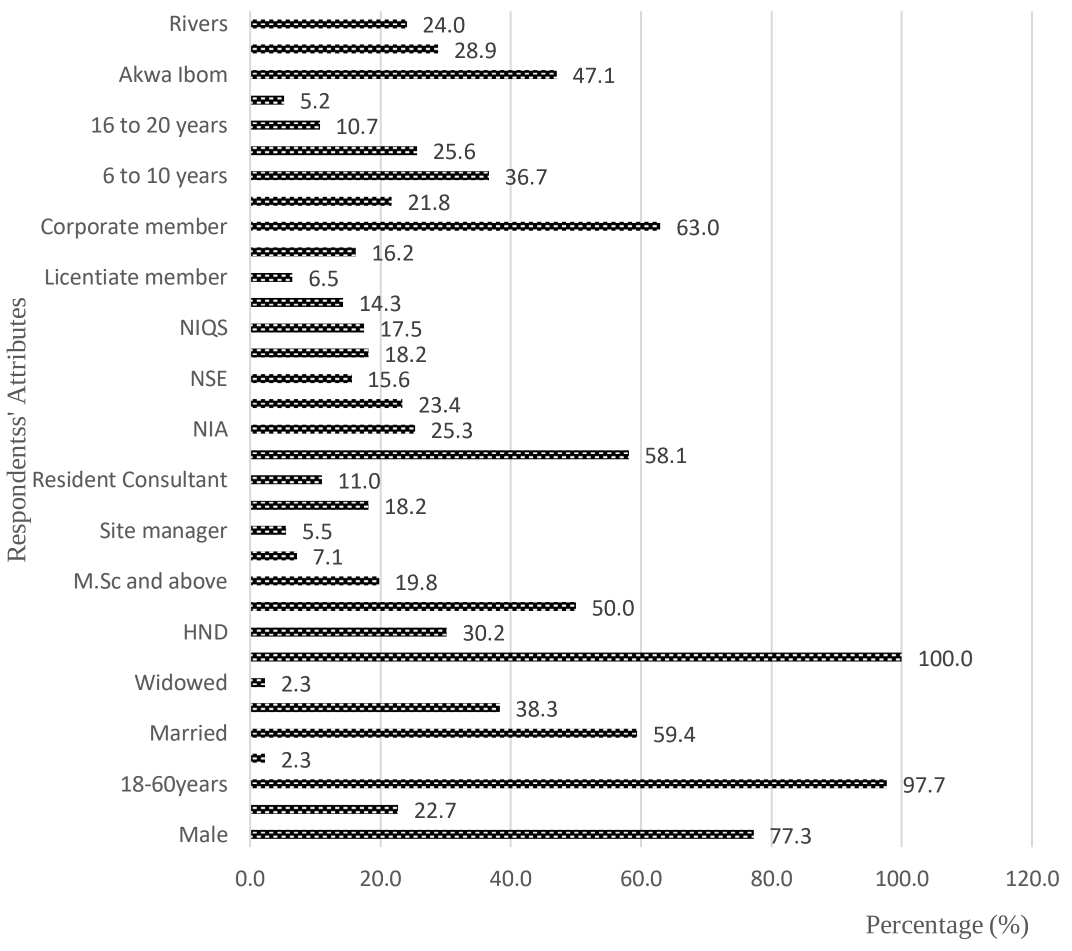

Figure 1: Respondents' Demographic Distributions

Figure 1 shows the academic qualification of the respondents, 19.8% of the respondents are employees with M. Sc. and above, 50.0% with B. Sc. Degree and 30.2% with HND. The breakdown revealed that substantial number of the respondents are literate enough to understand the questions or explanation given in the course of completing the questionnaire. The distribution of respondents' position is shown in Figure 1 which illustrates that 41.8% of the respondents are either project manager, site manager, site supervisor or resident consultant belonging to the decision-making (upper or middle management cadre) in their various organisations. While 58.2% are either engineers, or other professionals such as builders, quantity surveyors, architects who are in the employment of contractors. With the breakdown of the respondents constituting upper and middle management cadre indicates high interests in the study and high degree of reliability of their responses.

The distribution of respondents' professional affiliation is shown in Figure 1 which illustrates that 25.3% are architects; 23.4% builders; 33.8% being structural, mechanical, electrical or any other services engineers and 17.5% being quantity surveyors. This indicates the respondents' professional relevance in the construction industry, high interests and the great confidence in their answers. The distribution of respondents' professional competence equally shows that they are professionally qualified indicating reliability of their responses.

Figure 1 shows the respondents' years of experience, with cumulative of 41.5% of them having more than ten years of experience. The periods of experience of 36.7% of the respondents falls between six and ten years while the remainder were below five years of experience. Thus, the respondents possess considerable experience, and would understand issues relating to the use of impact of climate variability on construction activities on site. The analysis of the location of the respondents within the study area shows that 47.1% of the respondents operate in Akwa Ibom State while 28.9% are engaged in construction firms operating within Delta State and the balance of 24.0% worked in Rivers State. This indicates an even spread of the respondents across the study area covered by this study.

4.2 Assessment of Drivers of Climate Variability Based on State Basis

This study assessed the drivers of climate variability in some selected States of South-South geopolitical zone of Nigeria. The summary of the assessment of the drivers of climate variability on State basis is presented in Table 2. The assessment employed the use of mean score as a descriptive analytical tool to rank the various drivers of climate variability according to the perceptions of the respondents from each of the selected State in South-South geopolitical zone of Nigeria.

The analyses show that seven (7), four (4) and five (5) among the twenty variables driving climate variability which were assessed were rated greater or equal to the cut-off value of 3.00 in their respective States of Akwa Ibom, Delta and Rivers in that order. Table 2 shows topography, deforestation and solar radiation as the three most significant drivers of climate variability in each of the States representing the South-South region.

The result indicates that, the first three highest ranked drivers of climate variability in Akwa Ibom State are gas flaring from oil companies; solar radiation; and topography with mean scores of 4.02, 3.82, and 3.68 respectively. The values of the mean scores of these variables suggest that the respondents perceived them to either always or frequently being the reason for the climate variability in Akwa Ibom State. It is noted that heat generated from asphalt during placement; heat generated during concrete production; and chimney fumes from homes; with the mean scores of 1.54, 1.63, and 2.02 respectively are the three perceivably ranked lowest variables in Akwa Ibom State. A critical examination of these variables with the least mean scores show that they are either never or rarely being considered as significant contributors to climate variability.

The analysis of the drivers of climate variability in Delta State show that gas flaring from oil companies; topography; and solar radiation with the mean scores of 3.94, 3.86, and 3.82 respectively take precedence over other variables, ranking in the first three positions. The three least ranked variables contributing to climate variability in Delta are heat generated from asphalt during placement; heat generated during concrete production; and fossils from fertilizer plant with the mean scores of 1.53, 1.82, and 1.90 respectively are the three perceivably ranked lowest variables in Delta State.

Similarly, the result identified the three highest ranking drivers of climate variability in Rivers State to include solar radiation; gas flaring from oil companies; and deforestation with mean scores of 4.05, 3.93, and 3.64 respectively. On the other hand, carbon generated from vehicles during; heat generated during concrete production; and fossils from fertilizer plant with the mean scores of 1.62, 1.67, and 1.81 respectively are the least three variables in Rivers state. The implication of the result is that high and low rank variables portray the ones that are either always or often and either never or rarely being considered as drivers contributing to climate variability.

The results in Table 2 shows that among the highly rated drivers of climate variability in the zone are gas flaring from oil companies; solar radiation; topography; and deforestation, ranking in the first four positions with mean score values of 3.98, 3.851, 3.69 and 3.49 correspondingly. This study presents the phenomenon asserted by Recha *et al.* (2017) where respondents associated climate change and variability with deforestation and industrial pollution. The results also show that only about six (about 30.0%) out twenty variables of the assessed drivers of climate variability attained a significant level, with about 70.0% below the cut-off value of 3.00. The possible reason may be attributed to the type respondents of the study who are not climatologists, rather construction professionals but with fair knowledge of climate variability.

Table 2: Results of the Assessment of Drivers of Climate Variability Based on State

Drivers of Climate Variability	AKS		DTS		RVS	
	MS	**R**	**MS**	**R**	**MS**	**R**
Topography	3.72	3	3.76	2	3.46	4
Deforestation	3.46	4	3.35	4	3.81	3
Heat generated during production of steel.	3.01	6	2.82	6	3.45	4
Heat from energy needed to run a building like electricity	2.31	13	2.40	11	2.22	12
Heat generated during asphalt production	2.79	8	2.67	8	2.85	7
Carbon emission from exhaust fume of plants and equipment	2.77	10	2.94	5	2.85	7
Chimney fumes from homes	1.94	17	1.99	17	1.93	15
Gas flaring from Oil companies	4.08	1	4.07	1	3.89	2
Migration of people from rural to urban area	2.98	7	2.46	10	2.73	9
Burning of waste	3.19	5	2.75	7	2.95	6
Methane from animal.	2.14	14	2.07	15	1.81	18
Heat generated during concrete production	1.68	19	1.62	20	1.62	20
Fossils from fertilizer plant	2.04	16	2.04	16	1.84	17
Burning of coal	1.93	18	1.99	17	1.93	16
Carbon emission from electricity production	2.12	15	2.25	14	2.03	14
Carbon from cement plant	2.78	9	2.54	9	2.16	13
Carbon from asphalt plant	2.50	12	2.38	12	2.36	11
Solar radiation	3.88	2	3.74	3	4.11	1
Heat generated from asphalt during placement	1.52	20	1.74	19	1.64	19
Carbon generated from vehicles during transportation of materials	2.58	11	2.28	13	2.64	10

AKS = Akwa Ibom State; DTS = Delta State; RVS = Rivers State; N for AKS = 145; N for DTS = 89; N for RVS = 74; MS = Mean Score; R = Rank

4.2.1 Test of Hypothesis One

In view of the observed little discrepancies in the perceptions of the respondents from the different States selected for the study, it became vital to test the level of agreement or otherwise among the respondents from the different States. The result of the hypothesis, which was tested using Kendall's coefficient of concordance (W) test of agreement, was meant to provide a platform upon which inference could be made as to the degree the variation of the assessed drivers of climate variability vary from State to State could be generalised for the zone or that they are unique to each of the States. The results are presented in Table 3. With reference to Table 3, it can be inferred that there is perfect agreement among the respondents about contributions of the assessed drivers of climate variability in the South-South zone, Kendall's coefficient of concordance (W) being 0.967. The null hypothesis one is, therefore, rejected and the alternative upheld leading to the conclusion that there is significant agreement in the perceptions of the respondents about the drivers of climate variability among the States in the study area.

Table 3: Result of Test of Agreement (Hypothesis One)

Test Statistics	
N	3
Kendall's W[a]	.970
Chi-Square	55.275
df	19
Asymp. Sig.	.000

a. Kendall's Coefficient of Concordance

4.2.2 Assessment of Drivers of Climate Variability in South-South, Nigeria

It is observed that the both the scores and rankings of the drivers (as presented in Table 2) across the selected States for each of the variables are not the same considering the analysis based on respective State and hence, the number of significant drivers vary from State to State. Nevertheless, the test of agreement among the entire perceptions of all the respondents indicated a very good level of agreement based on the Kendall’s coefficient in the tested hypothesis one. Therefore, the analysis for the combination of all the States representing South-South geo-political region was run to determine the significant ones among the drivers on the one hand, and on the other hand, to enhance the establishment of the number of the drivers of climate variability significantly contributing to climate variability in the zone. The summary of the assessment of the drivers of climate variability for the total number of respondents for the study is presented in Table 4. The drivers of climate variability presented in Table 4 were analysed in descending order of their relative contribution to climate variability in the study area as perceived by the respondents for the study.

Table 4: Results of the Assessment of Drivers of Climate Variability in South-South

Drivers of Climate Variability	Sum	MS	Std. Dev.	R
Gas flaring from Oil companies	1241	4.03	0.90	1
Solar radiation	1200	3.90	0.88	2
Topography	1131	3.67	0.91	3
Deforestation	1082	3.51	1.11	4
Heat generated during production of steel.	942	3.06	1.11	5
Burning of waste	926	3.01	1.15	6
Carbon emission from exhaust fume of plants and equipment	875	2.84	1.10	7
Heat generated during asphalt production	853	2.77	1.15	8
Migration of people from rural to urban area	853	2.77	1.08	8
Carbon from cement plant	789	2.56	1.14	10
Carbon generated from vehicles during transportation of materials	772	2.51	1.04	11
Carbon from asphalt plant	750	2.44	1.11	12

Heat from energy needed to run a building like electricity	713	2.31	1.05	13
Carbon emission from electricity production	657	2.13	0.98	14
Methane from animal.	629	2.04	0.88	15
Fossils from fertilizer plant	614	1.99	0.90	16
Chimney fumes from homes	601	1.95	0.84	17
Burning of coal	600	1.95	0.80	18
Heat generated during concrete production	507	1.65	0.70	19
Heat generated from asphalt during placement	496	1.61	0.78	20

N = 308; MS = Mean Score; Std. Dev. = Standard Deviation; R = Rank

4.3 Determination of Extent of Climate Variability Impact on Construction Project Activities

The motivation of this study is to determine the impact of climate variability on construction project activities in the execution phase of construction projects in the study area. The analysis adopted the use of relative extent of impact as described in the methodology section of this study. Furthermore, the analysis was carried out according to the purposively selected four elements of climate variability vis-à-vis rainfall, temperature, humidity, and wind speed. The summary of the determination of the construction activities significantly impacted by climate variability for the total number of respondents for the study is presented in Table 5.

Table 5: Relative Extent of Impact of Climate Variability Elements on Construction Activities

Construction Project Activities	Rainfall		Temperature		Humidity		Wind Speed	
	REI	R	REI	R	REI	R	REI	R
Excavation of trench for foundation	0.818	5	0.637	1	0.344	16	0.408	14
Levelling of foundation trench	0.782	13	0.577	9	0.392	7	0.423	6
Reinforcement bars placement	0.746	18	0.381	29	0.333	22	0.445	2
Batching of concrete	0.787	12	0.447	20	0.360	11	0.426	5
Placement of in-situ concrete in foundation footing	0.845	3	0.618	4	0.467	3	0.433	4
Mixing of mortar for blockwork	0.827	4	0.599	6	0.340	19	0.499	1
Blockwork in foundation	0.754	17	0.453	18	0.327	27	0.422	11
Formwork to side of column in foundation	0.728	21	0.472	16	0.510	2	0.425	6
Concrete placement in column	0.686	24	0.451	19	0.454	4	0.436	3
Laterite filling to make up level	0.851	2	0.454	17	0.433	5	0.417	13
Compaction of laterite filling	0.718	23	0.518	13	0.367	9	0.423	6
Plain in-situ concrete in floor bed as oversite	0.740	19	0.636	2	0.384	8	0.423	6
Blockwork	0.814	9	0.444	22	0.419	6	0.401	16

Formwork to side and soffit of lintel	0.634	27	0.430	26	0.331	24	0.425	6
Column and lintel reinforcement	0.535	29	0.568	10	0.542	1	0.421	12
Concrete placement in lintel	0.595	28	0.556	11	0.323	28	0.408	14
Roof beam/concrete fascia	0.641	26	0.526	12	0.336	21	0.304	24
Installation of timber or concrete roof?	0.684	25	0.445	21	0.349	14	0.343	19
Installation of roofing sheets	0.727	22	0.492	14	0.330	25	0.258	27
Plastering of external walls	0.782	13	0.489	14	0.347	15	0.200	28
Screeding of external wall surface	0.818	5	0.412	27	0.343	18	0.200	28
Application of paint (prime coat and two finishing coat) on external wall	0.790	11	0.625	3	0.361	10	0.290	25
Cutting and filling of driveway	0.816	7	0.438	24	0.355	13	0.290	25
Laying of kerb stones	0.736	20	0.590	8	0.340	19	0.358	17
Concreting of pavement walkway	0.808	10	0.390	28	0.344	16	0.316	22
Excavation of septic tank and soak-away pit	0.870	1	0.436	25	0.290	29	0.319	21
Concrete blinding of septic tank bed	0.816	7	0.617	5	0.330	25	0.344	18
Blockwork in septic tank	0.780	15	0.597	7	0.357	12	0.310	23
Evacuation of excavated materials	0.767	16	0.443	23	0.332	23	0.323	20

N = 308; REI = Relative Extent of Impact; R = Rank

The results in Table 5 shows that among the highly rated construction activities being impacted by climate variability in the zone includes excavation of septic tank and soak-away pit; laterite filling to make up level, and placement of in-situ concrete in foundation footing, ranking in the first three positions as being impacted by rainfall. While the results in Table 5 shows that among the highly rated construction activities being impacted by temperatures as an element of climate variability in the zone includes excavation of trench for foundation; plain in-situ concrete in floor bed as oversite; and application of paint on external wall, ranking in the first three positions. Conversely, no construction activity is being significantly impacted by humidity and wind speed as elements of climate variability in the zone based on the cut-off point of 0.60 as decision rule.

4.3.1 Test of Hypothesis Two

In view of the observed little discrepancies in the perceptions of the respondents, it became vital to test the level of agreement or otherwise among the States. The result of the hypothesis, which was tested using Kendall's coefficient of concordance (W) test of agreement, was meant to provide a platform upon which inference could be made as to whether the degree to which the variation of the extent of impact of climate variability on construction activities vary from State to State could be generalised for the zone or that they are unique to each of the States. The results are presented in Table 6.

With reference to Table 6, it can be inferred that there is either substantial or perfect agreement among the respondents about extent of impact of climate variability elements (rainfall, temperature, humidity and wind speed) on construction activities in the South-South zone, Kendall's coefficient of concordance (W) being 0.89, 0.91, 0.73, and 0.86 for rainfall, temperature, humidity and wind speed respectively. The null hypothesis two is, therefore, rejected and the alternative upheld leading to the conclusion that there is significant agreement in the perceptions of the respondents about the extent of climate variability impact on construction project activities among the States in the study area.

Table 6: Result of Test of Agreement (Hypothesis Two)

Test Statistics	Rainfall	Temperature	Humidity	Wind Speed
N	3	3	3	3
Kendall's W[a]	0.85	0.9	0.7	0.86
Chi-Square	71.41	75.97	59.03	72.23
df	28	28	28	28
Asymp. Sig.	0.00	0.00	0.00	0.00

a. Kendall's Coefficient of Concordance

4.4 Determination of Critical Construction Project Activities Impacted by Climate Variability

The critical construction project activities impacted by climate variability were blotched with the use of inter-rater formula as expressed in Equations 5 and 6. The result of the descriptive analysis is presented in Table 7. The interpretation is according to LeBreton and Senter (2008), as adopted by Ekanem *et al*. (2020). At the end of the analysis, only 14 construction activities were spotted as critical ones based on the interpretation rule of $0.51 \leq x \leq 1$ for moderate agreement and above. Kulemeka, Kululanga, and Morton (2015) observed that attempting to manage all identified important/significant variables simultaneously and giving them all equal attention is virtually impossible. However, by adopting the Pareto rule of separating out the important few from the trivial many to focus attention on the key variables, success is more likely. Therefore, the analysis of the critical construction project activities was expected to identify the most significant variables that will adequately define or describe the impact of climate variability with respect to Pareto's principle. The Pareto principle (also known as the 80–20 rule) states that, for many events, roughly 80% of the effects come from 20% of the causes. Concomitantly, the number of variables derived could be explained by the Pareto principles, meaning that roughly 80% of the impact of climate variability on construction project activities could emanate from about 20%, which most likely are to be the critical ones.

In this view, the fourteen (14) activities representing about 48.27% of 29 identified activities that can be impacted by rainfall, which has adequately fulfilled the Pareto principle, and can satisfactorily define the impact of climate variability on construction projects in the study area. Excavation of trench for foundation; levelling of foundation trench; batching of concrete; mixing of mortar for blockwork; and excavation of septic tank and soak-away pit are some of the critical construction project activities vulnerable to climate variability as identified by this study. Similarly, nineteen (19) activities representing about 65.52% of the 29 assessed activities can be impacted by temperature. Such construction activities include batching of concrete; blockwork in foundation; formwork to side of column in foundation; concrete placement in column; formwork to side and soffit of lintel; and concrete placement in lintel. However, based on the evaluation results derived in the preceding section that no construction activity is being significantly impacted by humidity and wind, there is no need for identifying any critical activity impacted by the two elements of climate variability. The results derived by this study is consistent with the study of Marzouk and Hamdy (2013) where rainfall and temperature were asserted to have significant effect on formwork shuttering and removal. Hence, it was recommended that assignment of appropriate crew size for such construction activities be accorded adequate attention to meet project requirements with respect to total duration of project execution.

Table 7: Critical Construction Project Activities Impacted by Climate Variability

Construction Project Activities	Rainfall		Temperature	
	RWG	Dec.	RWG	Dec.
Excavation of trench for foundation	0.649	MA	0.188	LA
Leveling of foundation trench	0.660	MA	0.375	WA
Reinforcement bars placement	0.419	WA	0.643	MA
Batching of concrete	0.546	MA	0.548	MA
Placement of in-situ concrete in foundation footing	0.697	MA	0.315	WA
Mixing of mortar for blockwork	0.688	MA	0.368	WA
Blockwork in foundation	0.549	MA	0.688	MA
Formwork to side of column in foundation	0.288	LA	0.686	MA
Concrete placement in column	0.157	LA	0.618	MA
Laterite filling to make up level	0.570	MA	0.660	MA
Compaction of laterite filling	0.335	WA	0.159	LA
Plain in-situ concrete in floor bed as oversite	0.425	WA	0.037	LA
Blockwork	0.607	MA	0.667	MA
Formwork to side and soffit of lintel	0.026	LA	0.633	MA
Column and lintel reinforcement	0.356	WA	0.519	MA
Concrete placement in lintel	0.372	WA	0.520	MA
Roof beam/concrete fascia	0.339	WA	0.583	MA
Installation of timber or concrete roof?	0.262	LA	0.600	MA
Installation of roofing sheets	0.359	WA	0.608	MA
Plastering of external walls	0.369	WA	0.576	MA
Screeding of external wall surface	0.637	MA	0.692	MA
Application of paint (prime coat and two finishing coat) on external wall	0.573	MA	0.277	LA
Cutting and filling of driveway	0.563	MA	0.632	MA
Laying of kerb stones	0.353	WA	0.441	WA
Concreting of pavement walkway	0.450	WA	0.614	MA
Excavation of septic tank and soak-away pit	0.762	SA	0.668	MA
Concrete blinding of septic tank bed	0.615	MA	0.241	LA
Blockwork in septic tank	0.564	MA	0.474	WA
Evacuation of excavated materials	0.367	WA	0.668	MA

RWG = Rating Weighted Agreement; Dec. = Decision; VSA =Very Strong Agreement; SA = Strong Agreement; MA = Moderate Agreement; WA = Weak Agreement; LA = Lack of Agreement

5. CONCLUSIONS AND RECOMMENDATIONS

It was observed that the both the scores and rankings of the drivers of climate variability across the selected States for each of the variables are not the same considering the analysis based on respective State. Nevertheless, the test of agreement among the entire perceptions of all the respondents indicated a very good level of agreement based on the Kendall's coefficient in the tested hypothesis one. The result of hypothesis one provides a platform for inference that the assessed drivers contribute to climate variability of in the South-South zone. The null hypothesis one was rejected and the alternative upheld leading to the conclusion that there is significant agreement in the perceptions of the respondents about the drivers of climate variability among the States in the study area.

The result of the hypothesis two showed that there is either substantial or perfect agreement among the respondents about extent of impact of climate variability elements (rainfall, temperature, humidity and wind speed) on construction activities in the South-South zone. The Kendall's coefficient of concordance (W) value was 0.890, 0.91, 0.73, and 0.86 for rainfall, temperature, humidity and wind speed respectively. The null hypothesis two was, therefore, rejected and the alternative accepted leading to the conclusion that there is significant agreement in the perceptions of the respondents about the extent of climate variability impact on construction project activities among the States in the study area. More so, fourteen (14) construction activities representing about 48.27% of 29 assessed activities were identified to be impacted by rainfall, while nineteen (19) activities representing about 65.52% were identified to be impacted by temperature. Inversely, no construction activity is being significantly impacted by humidity and wind. Therefore, this study concludes that rainfall and temperature, as elements of climate variability, significantly impact on construction project activities, whereas humidity and wind do not.

Based on the findings of the study, it is recommended that relevant authorities at Federal and State governments levels should implement existing regulations to reduce the impact of climate variability on construction projects. More importantly, managements of construction sites should plan the critical construction activities prone to impact of climate variability as derived by this study against the catastrophic impact of climate variability.

6. Limitation of the Study

This study is limited to the use of three States to represent South-South region and the construction processes examined are limited to Building construction projects. Therefore, the result could be improved by further studies that captures all the States in the South-South geopolitical zone of Nigeria. Additionally, the construction processes can be extended to cover others which are not captured in this study. Despite of these limitations the result could provide reasonable insight into the extent to which climate variability can impact construction activities on site, as well as guide for further studies.

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