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Article

Impact of weather conditions on labours' productivity in the Nigerians' construction industry

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Abstract: Weather is almost inevitable and plays an important role in determining the duration of construction projects. The construction industry ultimately thrives upon the physical input, put in by the labours. The majority of the construction projects are executed in the outdoor environment and hence face a high impact of weather conditions. This study therefore evaluated the influence of weather conditions on construction workers' productivity in Jos, Plateau State and proceeded to make recommendations geared towards the improvement of construction workers' productivity in Jos. The study was conducted through the direct observation method. Three hundred and ninety-six (396) works were purposively sampled in selected working sites. The outcome shows that during dry weather, there was considerably less significant productivity of manual excavation. In contrast, a large increase in blockwork and plasterwork productivity was observed with a percentage difference of 33%, 56.3% and 61%, respectively. On the other hand, during wet weather conditions, the labour productivity for manual excavation increases, whereas it decreases for block work and plasterwork with percentages difference of 58%, 40% and 47%, respectively. Besides, relative humidity and wind speed have no impact on labours' productivity in dry and wet weather. Besides, the temperature has the most decisive impact on workers' productivity. Moreover, wind speed and humidity have a lower influence on workers' productivity. The construction industry stakeholder in Jos, Nigeria, would benefit from this study's recommendations for reducing the influence of weather on the building sector. Besides, the output can be extended to other regions having similar characteristics.

Keywords: labours productivity; weather; construction industry; Nigeria

1. Introduction

The construction industry is susceptible to climate change or any other kind of weather occurrence (Atibu, 2015). Consequently, working under hot weather conditions (warmer working sites) poses complications for construction projects (Holstein and Miller, 2017). Suppose the workers are not protected adequately in hot environments; they may easily accumulate heat from their surroundings, producing a drop in core temperature, normal organ function, water and salt imbalances, and other difficulties (Narocki, 2021). Similarly, cold or rainy weather (chilly working sites) can put labours at threat of developing cold stress. As wind speed boosts, it results in a cold air temperature, boosting the risk of cold pressure for exposed labours who are working outdoors (Moda et al., 2019). Radevsky and Taylor (2012) indicated that weather conditions impact employee productivity, quality of performance, level of

wastage, and labour turnover. Unhealthy, unpleasant, and uncomfortable working conditions contribute to job unhappiness and poor productivity.

According to Akinbode et al. (2008), safety measures are critical in every organisation. While looking for a job, many individuals desire decent working circumstances, including pleasant weather and staff health and safety. In general, outdoor executed construction projects are directly affected by weather conditions (Hasan et al., 2018; Musarat et al., 2021a). The influence of climate on construction events can reduce labour productivity or work stoppage. The climate-related work stoppage is ascribed to the incapability of workers under extreme conditions (Alaloul et al., 2021; Musarat et al., 2021b; Senouci et al., 2018). Weather is one of the primary causes triggering cost overruns and delays on construction projects (Abusafiya and Suliman, 2017; Durdyev, 2020; Musarrat et al., 2017). Setzer and Benjamin (2020) discovered that half of the construction activities are affected due to climate situations.

Various research has been performed to determine the correlation between weather conditions and labour productivity for construction activities (Manoharan et al., 2017; Raziq and Maulabakhsh, 2015; Rupp et al., 2015; Shanker et al., 2017). Schuldt et al. (2021) and Jung et al. (2016) studied the influence of climate on work and identified daily rainfall levels that cause construction operations to be halted and interrupted. The proposed method calculates the influence of weather on construction operations, considering lower labour productivity and disruptions that cause work stoppages. It aids in evaluating the influence of weather on construction duration and productivity, making it easier to create realistic timetables, cost projections, and credible bids. Olubajo and Babatunde (2017) came up with a plan for a hybrid expert system for scheduling and planning in construction that reflects how weather affects worker productivity.

Senouci et al. (2018) examined the labour productivity that is affected by the weather impact in Qatar. Wind, temperature and humidity were the key factors taken were considered. The output showed that the major cause of project delay is due to the low labour productivity which is caused by the extreme weather conditions. Besides, it was highlighted that in summer the productivity is half in comparison to winter conditions. Alrefaie et al. (2023) examined the influence of tropical countries' weather on labour productivity and considered Malaysia as the case study. It was explained that the shift of up to 43% in labour productivity is due to the factors that are related to the weather conditions. Under extreme weather conditions, labour productivity and supply are affected, mainly in tropical regions. Southeast Asia, South Asia and Sub-Saharan Africa are extremely in danger due to global warming future alerts (Dasgupta et al., 2021).

The construction Industry ultimately prospers upon the physical input of the labours (Harvey et al., 2018; Yuan et al., 2018). Similarly, Nigeria is one of the most labour-dependent industries. Studies have shown that extremely hot summers and heat waves have greatly affected the Nigerian construction industry (Raimi et al., 2021; Rehman et al., 2022). In Plateau State, two weather conditions (dry and rainy weather annually) depending on calendars, have been recognised and distinguished for various reasons, including agriculture, building, and industry (Padwe, 2020; Solomon Zi and Hyacinth M, 2020). The dry season stays from December to May, while the rainy from June to November, as shown in **Table 1** (Ekoh, 2020; Lee, 1972; Ogunrayi et al.,

2016). In 2009, Jos Airport's annual rainfall was much greater than in the previous four years (Ekoh, 2020; Lee, 1972).

Table 1. Ecological and meteorological aspects of the Jos Plateau, Nigeria (Ekoh, 2020; Lee, 1972).

Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Weather Condition	DRY						RAINY					
Temperature	COLD			HOT			COLD					
	COLD DRY			HOT DRY			COLD RAINY					

Knowledge gap, study aims, objectives and significance

Despite the significance of climatic conditions on a regional and national level, little research has been done on how they affect the productivity of construction workers in many developing nations, including Nigeria (Alinaitwe et al., 2007; Ebele and Emodi, 2016). There is a need to improve the quantifiable effects of weather in the Nigerian construction industry which requires foremost attention. Thus, the objective of this study is to evaluate the influence of weather conditions on the productivity of construction workers in Jos, by this, the study gap will also be overcome. In this study, the data was collected from four separate building sites in Plateau state, Nigeria, and three different construction trades: manual excavation, plastering/rendering, and blockwork, where skilled labour, semi-skilled labour, and unskilled labour were the respondents. Skilled labour is that who is fully trained, semi-skilled labour knows the work but still requires further training, while unskilled labour is the one who needs to learn from the beginning. The output of the study will determine helpful guidelines for the stakeholders to schedule the project according to weather conditions and follow some protective precautions. Although the work is limited to the Nigerian construction industry, the output applies to those countries' industries which possess similar concerns in labours' productivity due to the impact of the weather.

2. Research methodology

This work was pursued through a survey research design by considering both quantitative and qualitative research strategies, as reflected in **Figure 1**. The selected study area was the construction sites in Jos which are located in the North-central part of Nigeria. This state was chosen because of the high rates of weather conditions and high rates of construction sites within the state (Kamta et al., 2020; Ogunode and Kolo, 2021).

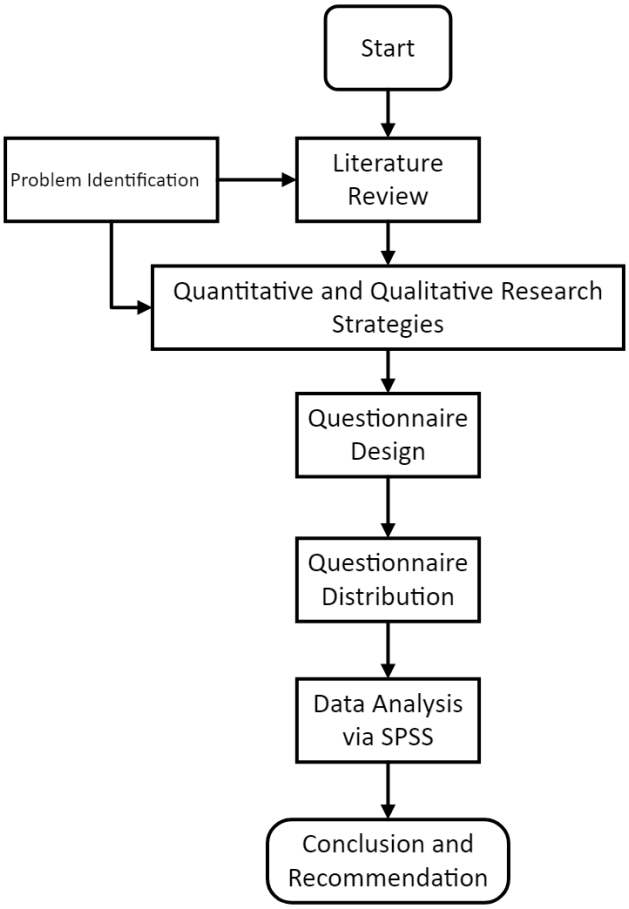

Figure 1. Research flowchart.

2.1. Sampling strategy

A Stratified sampling technique was adopted to select the required respondents from the study population which was divided into different strata (crews) and the number of elements from each stratum was selected based on the available units (elements) in those strata. The sample consisted of male participants between the ages of eighteen (18) and twenty-five (25) in Skilled Labour, Semi-Skilled Labour, and Unskilled Labour. The labour crews were considered instead of individuals in this study. Therefore, they deemed the best groups to fulfil the objectives of this study. The study identified 400 numbers of labours and adopted the approach of using published tables of Krejcie and Morgan tables (Krejcie and Morgan, 1970). The sample size was determined as 396 based on the population size of 400 in the study, the details are reflected in **Table 2**.

Table 2. Respondents' distribution and details.

Type of Trade	Skills labours	Semi Skills labours	Unskilled labours	Total number of Respondents	% of the Total
Manual Excavation	45	45	46	136	34.34
Block Work	40	40	40	120	30.30
Plastering Work	45	47	48	140	35.35
Total				396	100

2.2. Methods of data collection

The study demands an everyday compilation of data regarding the efficiency of work. It also involves an evaluation of how the efficiency of construction trades varies during the year due to temperature, wind speed, and humidity. The crew productivity data were gathered and analysed for March-April (dry weather) and June-July (wet weather). The weather data was also collected; accordingly, which consisted of daily temperature, wind speed, and humidity. Thus, direct observation was the main instrument for collecting data in this study. The main reason is that questionnaire survey-based studies do not accurately assess the impacts of weather conditions. The questionnaire survey depends mainly on human judgments. This study targets ordinary construction workers working on different construction sites in Plateau State. Construction site measurements were held in Plateau State after obtaining approval from the site management. Participation was voluntary and divided into crews according to their trades and daily tasks.

2.3. Data analysis

The data obtained using direct observation was thoroughly screened and analysed with Microsoft Excel and Statistical Package for Social Sciences (SPSS) v21. The data reliability and internal consistency were checked and forwarded for data validity. Validity shows how accurate the measurements are and is also a reflection of sample representativeness. The robustness of survey design impacts validity and whether the instrument measures what it is supposed to measure is the core of validity estimation. The instrument has qualified the discriminant validity criterion, convergent validity criterion and concurrent validity criterion (Construct Validity—Criterion).

3. Results and discussion

The impact of weather on labours' productivity in Jos is assessed for three different construction trades: manual excavation, blockwork, and plasterwork. The assessments are made by recording the work volume performed by the crew members through direct observation daily. Practically in Jos, two kinds of weather, i.e., dry and wet, are experienced and assessed separately for each chosen trade.

3.1. Labours productivity during dry weather

During the dry weather, the work volume done by the labours is observed for manual excavation, blockwork and plasterwork. In dry weather, the work done of manual excavation is recorded as low due to the negative impact of temperature on labours' productivity. **Figure 2** illustrates the temperature level (histogram) and manual excavation (Frequency curve) during dry weather. According to the data, the temperature intensity on the soil is considerable, which makes the soil extremely difficult to excavate because of its consistency manually. In addition, the intense heat affects the bodies of the workers, which causes them to become drowsy. As a result, labour productivity was poor during the month of dry weather conditions. Moreover, the observations found that the productivity of manual excavation work volume was low during March and April, reaching the minimum value of $8m^3$/crew/day on Thursday, 08/04/2021. Whereas the maximum value of $12m^3$/crew/day was achieved

on Saturday, 03/04/2021, indicating a 33.33% percentage difference.

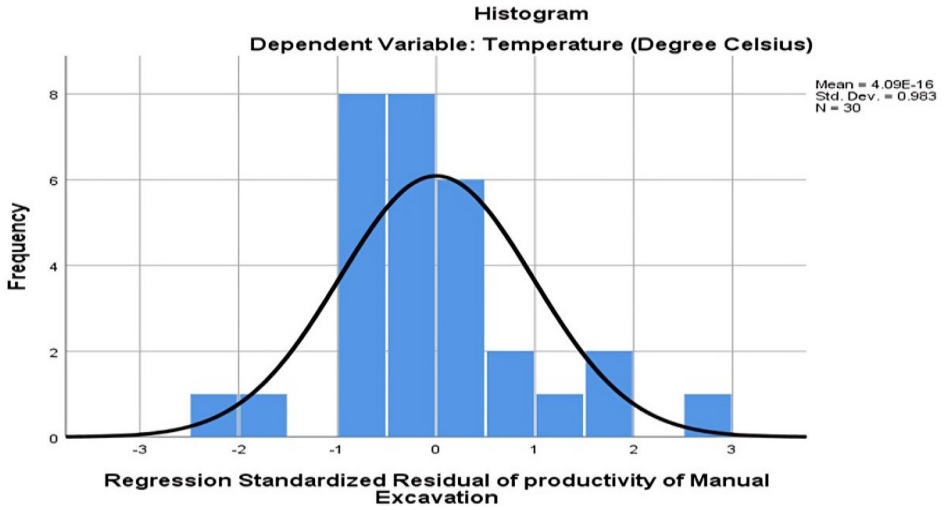

Figure 2. Temperature against the productivity of manual excavation March/April.

In contrast, during March and April, a positive impact of the temperature was noticed on labour productivity and blockwork volume. Minimum productivity of 22m^2/crew/day on Saturday, 03/04/2021, while maximum productivity of 50.2m^2/crew/day on Wednesday, 14/04/2021 was noticed as an equal percentage difference of 56.3%. The output in **Figure 3** demonstrates the impact of temperature on the productivity of blockwork during dry weather.

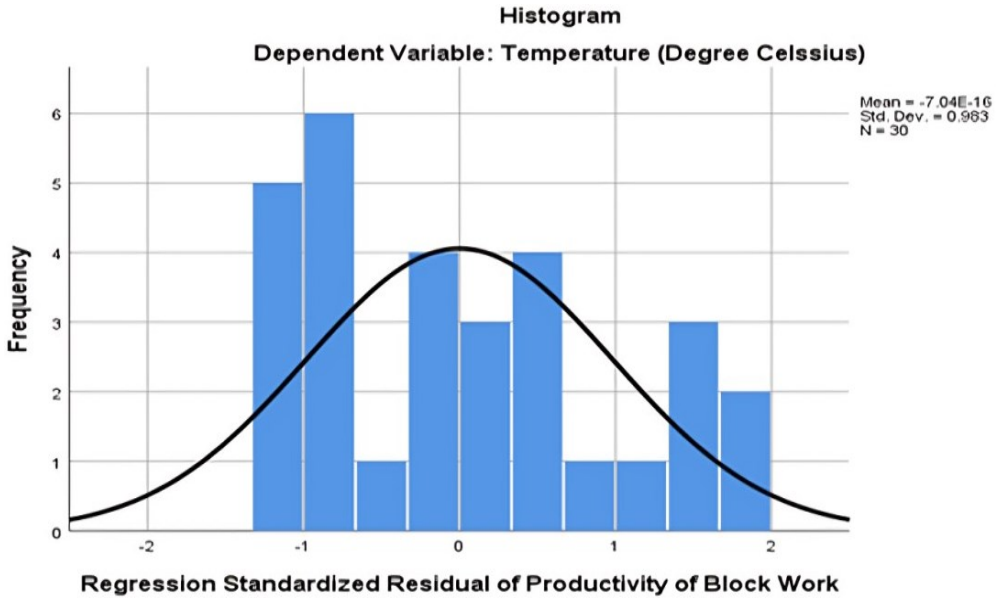

Figure 3. Temperature against the productivity of blockwork March/April.

Similarly, in response to the effect of temperature on plastering work volume during dry weather, the results indicate a significant boost in plastering output when the weather is dry. Furthermore, on Monday, 5 April 2021, the plastering production reached a minimum of 18.3 m^2/crew/day. On the other hand, on Saturday 24/04/2021, it peaked at 47m^2/crew/day. The percentage difference between the minimum and maximum production is found to be 61%. **Figure 4** shows a histogram of temperature

against work productivity.

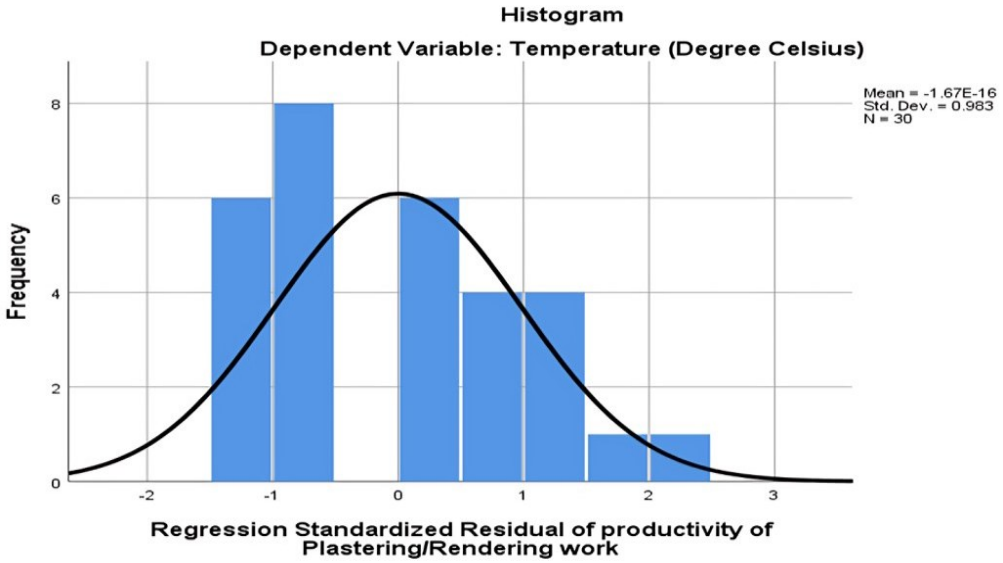

Figure 4. Temperature against the productivity of plastering work March–April.

Impact of humidity and wind speed during dry weather

The humidity and wind speed also significantly impact the weather conditions, thus important to consider their impact on labour productivity. In **Figure 5**, multiple bars illustrate the impact of relative humidity conditions on construction labour productivity during dry weather. While examining the impact of humidity in dry weather, relative humidity has no impact on the productivity of plasterwork, blockwork or the productivity of manual excavation work during dry weather (March and April). Similarly as indicated in **Figure 6**, upon observing the impact of wind speed during dry weather, no impact was observed on the productivity of manual excavation, blockwork, and plastering during dry weather conditions (March–April).

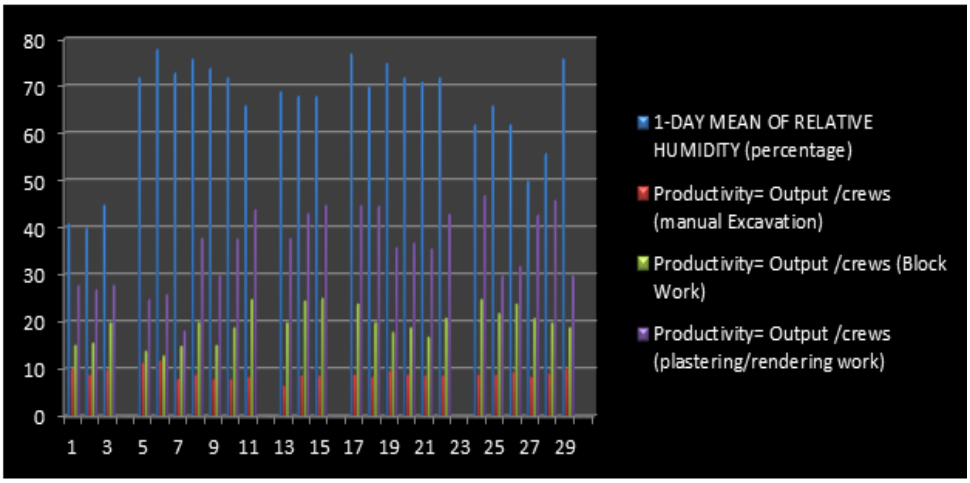

Figure 5. Relative humidity against the productivity of manual excavation, blockwork and plastering work in March–April.

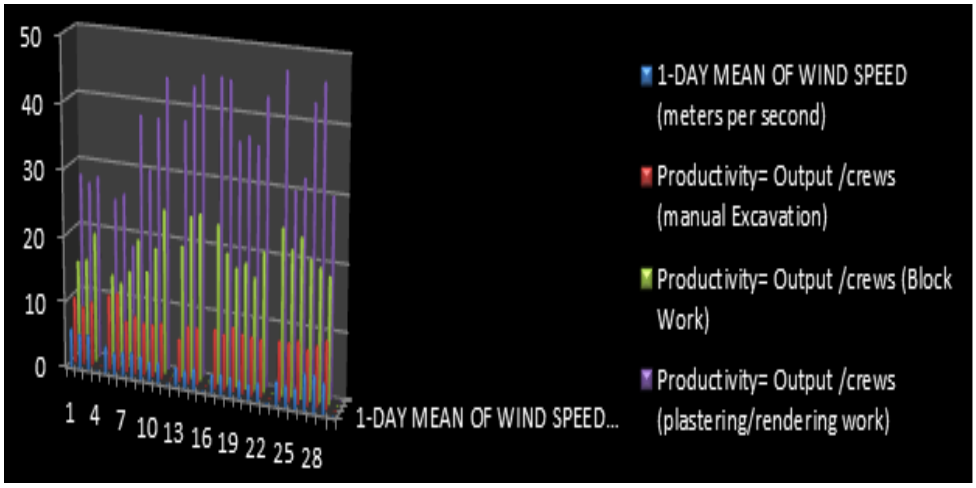

Figure 6. Wind speed against the productivity of manual excavation, blockwork and plastering work March–April.

3.2. Labours productivity during wet weather

The second most important weather condition in Jos, Nigeria, is the wet or rainy season. Monthly rainfall in Jos varies greatly throughout the year. The rainy season in Jos lasts about 7.2 months, with June, July and August being the month with the greatest rainfall. During wet weather conditions, the work volume for the manual excavation, blockwork, and plasterwork is assessed to determine the weather's impact. The findings indicate that the intensity of the temperature had no detrimental effect on the productivity of manual excavation triggered by moist soil. Consequently, manual excavation output is at its highest in June and July. The manual excavation productivity reached the minimum value of 8.4 m^3/crew/day on Friday, 18/06/2021. On the other side, on Monday, 05/07/2021, it achieved a maximum of 20 m^3/crew/day. The difference between the lowest and highest levels of productivity is 58%. **Figure 7** shows a histogram and frequency curve that demonstrates the influence of temperature on productivity in manual excavation to address the impact of weather conditions on construction workers' productivity during rainy weather.

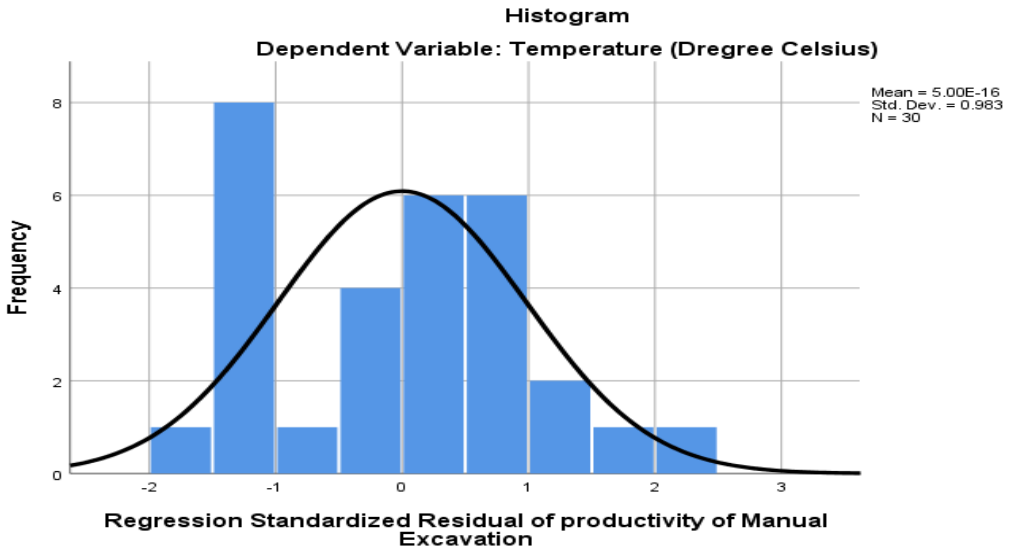

Figure 7. Temperature against the productivity of manual excavation June/July.

Besides, because of the excessive rainfall, this finding shows that the intensity of temperature on blockwork productivity negatively influences work volume and labour productivity. The influence of temperature on the productivity of blockwork is shown graphically in **Figure 8**. Rainfall in June and July disrupts work on-site and reduces output to 29.7 m^2/crew/day on Thursday, 01/07/2021, and 49.5 m^2/crew/day on Saturday, 21/07/2021. The difference in percentage between the lowest and greatest productivity figures is 40%.

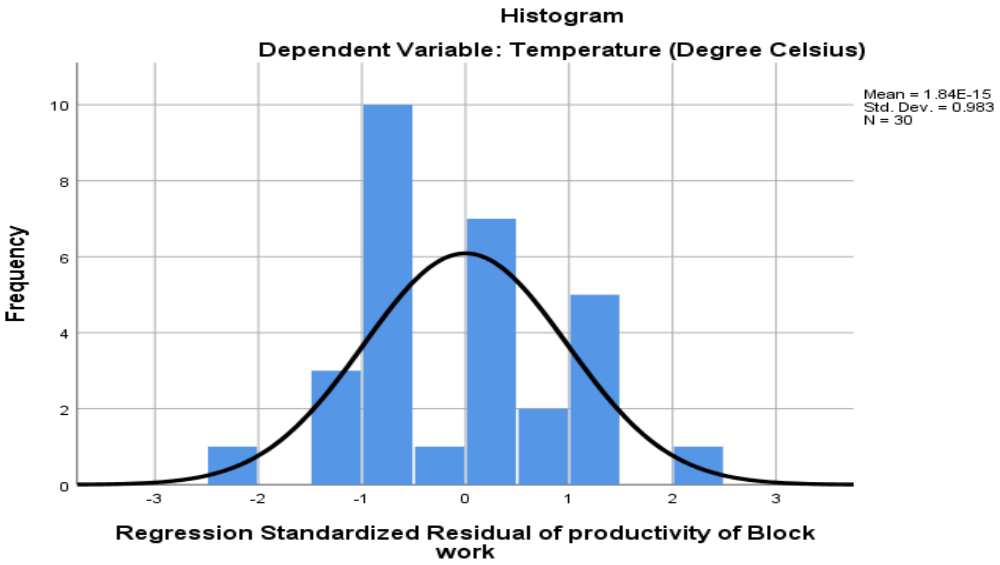

Figure 8. Temperature against the productivity of blockwork June–July.

Similarly, the results discover that plastering work volume is much slower in wet weather than in dry weather. Thus, when the weather is wet, the temperature has a detrimental influence on labours' productivity and plastering output. **Figure 9** describes a frequency histogram and a frequency curve in response to the impact of weather conditions on construction industry labours' who perform plastering work during rainy weather. Besides, the plastering production throughout June and July was poor, reaching the minimal value of 19 m^2/crew/day on Thursday, 10/06/2021. On the other side, it peaked on Saturday, 7/09/2021, at 36 m^2/crew/day. The difference between the minimum and maximum productivity levels is 47%.

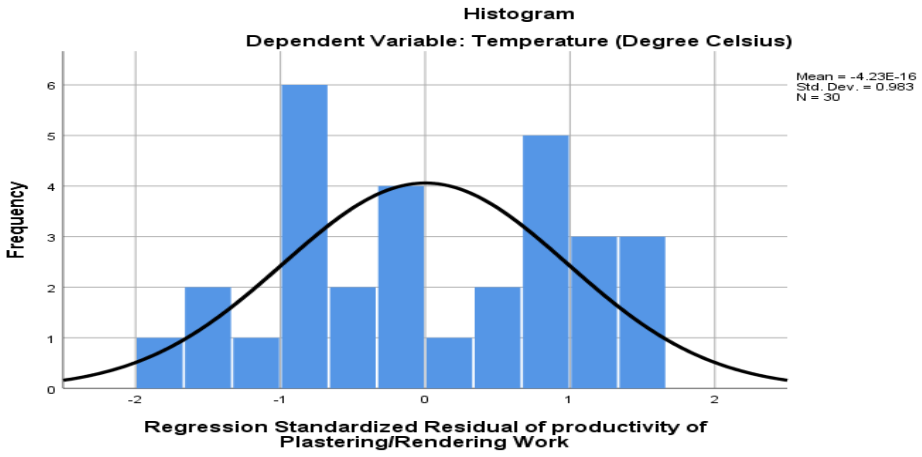

Figure 9. Temperature against the productivity of plastering work June–July.

Impact of humidity and wind speed during wet weather

While determining the impact of relative humidity, no impact was found on the labour productivity of manual excavation, blockwork and plastering during wet weather. **Figure 10** illustrates the relative humidity variance on each endogenous dimension, such as manual excavation productivity, blockwork, and plastering. Similarly, the results indicate no effect of wind speed on the productivity of manual excavation, Productivity of blockwork and Productivity of plastering during wet weather. **Figure 11** shows multiple bar chart outputs of the productivity of manual excavation, blockwork and plastering on wind speed during wet weather.

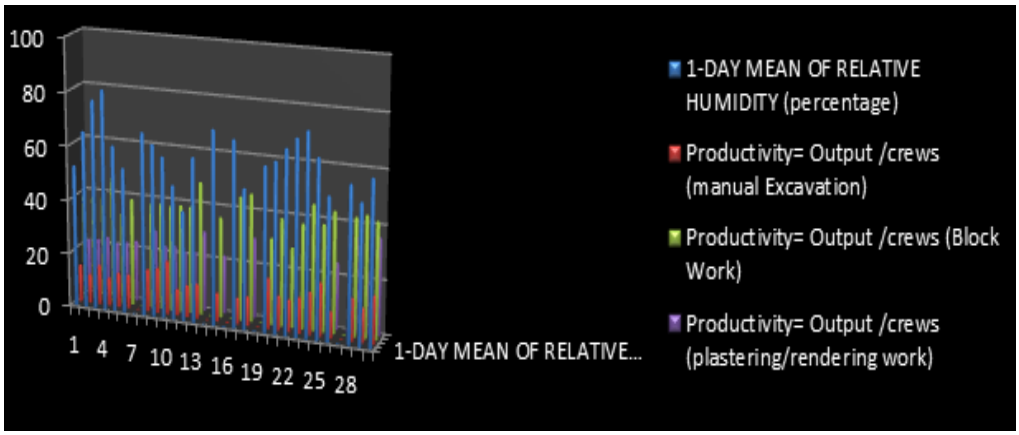

Figure 10. Relative humidity against the productivity of manual excavation, blockwork and plastering work June–July.

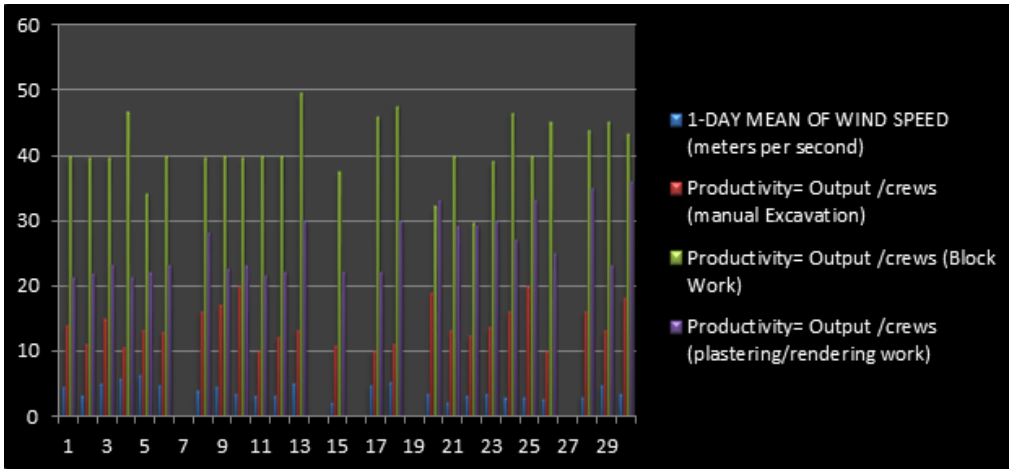

Figure 11. Wind speed against the productivity of manual excavation, blockwork and plastering work June–July.

3.3. Comparing impact of wet and dry weather

For the purpose of this study, the productivity difference judgment was used to determine and compare the productivity of the labours in dry and wet weather for different trades. The percentage difference was ranked from very low to high such as very high ≥ 71%; high = 70%–51%; low = 50%–31% and very low = 50%–31%. **Table 3** describes the percentage productivity difference; the result shows the three trade percentage productivity differences during dry and rainy weather conditions. The

manual excavation during dry weather conditions constitutes 33%, blockwork at 56.3% and plastering work at 61%, respectively, while percentage productivity differences during rainy weather conditions are; manual excavation at 58%, blockwork at 40% and plastering work at 47%, respectively.

Table 3. Percentage productivity difference %.

Weather	Trades	Minimum productivity	Maximum productivity	percentage difference %	Remark
	Manual Execution	8 m^3	12 m^3	33.33	Low
Dry weather	Block work	22 m^2	50.2 m^2	56.30	High
	Plastering	18.3 m^2	47 m^2	61.00	High
	Manual Execution	8.4 m^3	20 m^3	58.00	High
Wet weather	Block work	29.7 m^2	49.5 m^2	40.00	Low
	Plastering	19	36	47.00	Low

4. Conclusion

This research work aimed to assess the influence of weather conditions on construction workers' productivity. A questionnaire-based approach was adopted to pursue the impact area which was analyzed statistically. Based on the study findings, the following conclusions were drawn:

- The study finds that there is no significant productivity of manual excavation during dry weather conditions. The study further unveils that there is a large increase in block work and plaster work productivity during dry weather conditions. Moreover, trade percentage productivity difference during the dry weather conditions are manual excavation constituted 33%, block work at 56.3% and plastering work at 61%, respectively. The study also finds that there is no effect of relative humidity and wind speed on the productivity of manual excavation, block work and plastering during dry weather.
- The study unveils that, the productivity of manual excavation increases during wet weather conditions, furthermore, the findings of the study outweigh the graphical illustration demonstrating the decrease in block work and plaster work productivity during wet weather conditions. However, the percentage productivity difference during wet weather conditions is manual excavation at 58%, block work at 40% and plastering work at 47%, respectively. It was also observed that there is no effect of relative humidity and wind speed on the productivity of manual excavation, block work and plastering during rainy weather conditions.
- The study also underweighs that the temperature has the strongest impact on workers' productivity. On the other hand, wind speed and humidity have a lower impact on workers' productivity.

5. Recommendations

Based on the findings of this research, the following recommendations are made to improve the efficiency of workers' productivity in construction projects.

- Breaks must be given to avoid the tiredness of the workers if they continue to

work nonstop.

- The contractor needs to consider the impact of weather conditions on construction activity duration during the schedule of projects.
- The study is beneficial for the stakeholders to look into the matter with more in-depth knowledge to tackle the weather impact more concisely.
- The outcome can further be extended to regions with similar issues of labour productivity influenced by weather conditions.

6. Future directions

The focus of this study was on the building construction business in Jos, Plateau State, which included commercial, educational, and government facilities. Research might be done in various areas of construction projects such as other building trades, such as plumbing, drainage, mechanical work, HVAC, and painting, which should also be studied. Also, transportation projects need a study similar to this one to find out what affects the productivity of highway construction. This will help transportation departments avoid unnecessary cost increases and project schedule delays. The research can further be extended to other regions as well where a comparison can be made.

Authors contributions: Conceptualization, NU and SDT; methodology, NU and SDT; software, NU and SDT; validation, WSA and MAM; formal analysis, NU and SDT; investigation, NU and SDT; resources, NU and SDT; data curation, NU and SDT; writing—original draft preparation, NU and SDT; writing—review and editing, WSA and MAM; visualization, WSA and MAM; supervision, NU, WSA and SDT; project administration, NU, WSA and SDT; funding acquisition, WSA and MAM. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest: The authors declare no conflict of interest.

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