

Impact of Weather Conditions on Construction Workers Productivity: A Study of Selected Construction Sites in Jos, Plateau State

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Abstract

The objective is to determine worker's productivity output during wet and dry weather. The area of study was Jos. One hundred and ninety-six (196) operatives were sampled through stratified sampling techniques in twenty-five (25) selected construction sites. Trade operations selected were limited to manual excavation, blockwork and plastering operations. The operatives were observed on site on daily basis throughout the research period. Watch and thermometer were employed to measure the time taken daily to execute a given task at a specific site temperature. The study deployed descriptive statistics such as histogram, frequency curve and percentages; and inferential statistics such as regression standardized residual for data analysis, to evaluate the extent to which weather affect worker's productivity. The results show a 58% productivity difference between minimum and maximum output for manual excavation, it shows a 56.3% productivity difference for blockwork during dry weather, and a 61% productivity difference for plastering operation during wet weather. Therefore, it was concluded that dry weather increases the output of workers for blockwork and plaster operations while its output reduces during wet weather, and wet weather increases worker's productivity for manual excavation during wet weather, but reduces during hot weather. Therefore, this research recommends that weather effect on worker's productivity should be adopted by contractors and construction professionals when planning any project. In addition, construction activity should start early especially during dry weather for maximum output to be achieved before intense heat set in, also overall coats and helmet should be made available in cases of wet weather condition.

Keywords: Productivity, Weather, Manual Excavation, Blockwork, Plastering.

Introduction

Construction Industry thrives ultimately upon the input which are physically applied by the construction workers. In fair and actual fact, the construction industry is one of labor dependent industries who operates with the physical ability of human. It is the groundwork of the workers or craftsmen per say, which ultimately runs this industry. The concern presently is the hazardous nature and constant change in the atmosphere of the working environment which has great impact on the productivity and performance of workers on site. This result from the hazardous working environment has a major impact on workers' safety, health, performance and productivity (Umaru, 2013). Construction projects are in

most cases executed in an outdoor environment, and are therefore affected by weather conditions. Weather impact was reported to be one of the main factors causing delay and cost overruns on construction projects (Koehn and Meilhede 2018). Considerable number of construction activities is sensitive to weather conditions. According to Benjamin *et al.* (2017) almost 50% of construction activities are sensitive to weather conditions.

The effect of weather on construction activities can be in the form of reduced labor productivity and or work stoppage. Reduced labor productivity is generally attributed to reduced human performance due to heat or cold stresses resulting from the combined effect of temperature, humidity, and wind velocity. Weather effect during construction may lead to inability of construction personnel to work under severe conditions of heavy rain, hot and gusting winds and this may simply lead to non-compliance with safety regulations in such adverse weather conditions. Productivity is generally defined as the average direct labor hours required to install a unit of material. The term "productivity" expresses the relationship between outputs and inputs (Borcherding and Liou, 2016). Weather is the condition of the atmosphere at a particular place over a short period of time in terms of temperature, sunshine, wind, humidity and rain.

The construction industry is vulnerable to weather effect due to the nature of how construction companies operate and the industry's heavy reliance on manpower. Mills (2013), mentions that the construction industry due to its nature of operation is one of the most vulnerable to climate change. Due to the construction industry's mode of activities, it is subjected to high vulnerability of any form of climate change or weather event. As explained by Brodoli (2010), dry weather/heat waves can cause productivity of firms to fall beyond expectation thereby causing projects to be delayed. Exceptionally hot summers and heat waves have had a considerable impact on the construction activities in Nigeria (Umaru *et al.*, 2013).

The construction industry is exposed to different challenges during hot weather, which is not limited to poor performance and low productivity. In hot temperature, the construction worker is subjected to high intensity labor activities due to change in environmental weather factor, which make the body to easily accumulate heat thus making it difficult for the internal organs to function properly leading to decline in strength and activities the body can handle. This is a situation where the body loses salt and water which lead to salt imbalances and other health related issues in the body system. When the heat absorbed by the body exceeds the physiological range of human body temperature regulation, it may lead to several types of heat diseases. Also, Environmental cold and rain can affect any worker exposed to it at high temperatures, this exposes workers to risk of cold stress. As wind speed increase causes the cold temperature to be high, thereby increasing the risk and exposing workers to cold stress, especially those working outdoors, or those exposed to direct weather, when the construction activity is at early execution stage.

High weather condition such as hot weather and high rainfall causes work stoppage and most times interrupt the flow of construction activities leading to poor productivity,

wastage of resources, reduced profit for contractor, health related issues, increase in total cost of project and generally lead to poor performance in delivery of project. A system that provides a comprehensive estimate of weather impact, accounting for reduced labor productivity and interruptions causing work stoppage, on construction productivity is of practical value is neglected. This assists in quantifying weather impact on productivity and its effect on the duration of construction activities; and this will facilitate the preparation of realistic schedules, cost estimates, and reliable bids.

In essence good working conditions which includes the good weather condition, health and safety of employees should be a priority to every contractor, consultant and the client. Poor weather condition leads to inadequacy and poor performance by workers, with workers shows negative attitude towards activities. Human activities and attitude towards work can be driven by nature of weather and climate. In many situation workers carry out activities on average weather conditions and many workers are sensitive to extremes. However, there is need to enhance measurable impacts of weather conditions on construction worker's productivity in building construction sites. Despite the importance of weather nationally and regionally, little is documented on their effect on construction worker's productivity in many developing countries, including Nigeria (Sumanth *et al.*, 2014). This study would address the impacts of weather conditions on construction worker's productivity in Jos.

Statement of the Problem

Delay in project delivery is not a new problem which bedeviled performance in construction industry and construction activities in Jos. In many cases, when the projects are delayed in many cases, construction activities are extended which leads to additional incurred cost. Different factors contribute to delay in construction process and the negative impact is high on project delivery. One of the major factors that lead to project delay in weather condition in Jos. Construction projects, in general, are executed in an outdoor environment, and therefore affected by varying weather conditions. Weather impact was reported to be one of the main factors causing delay and cost overruns in project delivery (Koehn & Meilhede, 2015). Considerable number of construction activities is sensitive to weather conditions. Benjamin *et al.* (2017) almost 50% of construction activities are sensitive to weather conditions. Reduced labour productivity is generally attributed to reduced human performance due to effect of temperature, humidity, and wind velocity. Weather-related work stoppage is attributed either to the inability of construction personnel to work under severe weather conditions of heavy rain, snow, and (or) gusting winds or hot and intense heat situation.

According to Aderinto *et al* (2016), Plateau State has faced various weather conditions in the recent past, including heavy winter, heat waves, heavy rainfall, extreme temperatures, and flooding. Such weather conditions occur more frequently in the Plateau State. This weather situations according to Olomolaiye *et al* (2017) contributes to employee's

productivity in different forms such as, quality output, poor productivity, level of wastage and rate of turnover. Despite the importance of weather conditions both regionally and nationally, little is documented on their effect on construction worker's productivity in many developing countries, including Nigeria (Sumanth *et al.*, 2014). This study would address the impacts of weather conditions on construction worker's productivity in Jos. The problem has not been addressed in Plateau State.

Research Objectives

1. To determine the construction worker's productivity during dry weather condition
2. To determine the construction worker's productivity during wet weather condition
3. To determine the most affective weather component by comparing the impact of dry and wet weather condition on the worker's productivity in Jos.

Literature Review

Weather and Climate

According to Biparva *et al* (2010), weather and climate can be used interchangeably, but they actually represent different parts of the same spectrum. The immediate change of climatic conditions in a specific region with time which is usually measured within short periods which include hours or days can be termed as weather. Climate is the average state of the atmosphere and the underlying land or water in a particular region over a particular time-scale. furthermore, climate is what you expect at a particular period and weather is what you get. Climate variability is the variation around the mean climate and this includes weather variations and irregular events such as the El Nino/Southern Oscillation.

According to Andrews *et al* (2015), typically weather is the summary statistics of a set of atmospheric and surface variables such as temperature, wind, humidity, soil moisture, cloudiness, precipitation, thickness and concentration of sea ice and sea surface temperature. The official average value of a meteorological element for a specific location over 30 years is defined as a climate. Climate is used normally to compare current conditions and are calculated every ten years. Change in weather globally affect human health via pathways of varying complexity, scale, directness of the weather and with different timing. The impacts of weather also vary according to geographical locations, function of environment, topography and population. Impacts of weather not always negative, can also be positive, although expert in scientific reviews anticipate predominantly negative effect. This is no surprise since climatic change would disrupt and affect wide range of natural physical and ecological systems that are an integral part of Earth's life and support system. The impacts on health is on those who are directly exposed to changes in weather events both heat waves and winter cold. The increases in events of floods, storm-surges, droughts also have effect on human activities. The extent of change in the intensity, frequency and location of weather events due to climate change remains uncertain (Akinbode *et al*, 2011).

Impacts of Weather and Climate Changes on Human Activities

In many cases, workers and general human activities depend on climate and weather at a specified period to time. Workers rely on average conditions to perform. Large populations are sensitive to extreme weather condition. Aside from selecting and operating in a particular weather and climate conditions by selecting the right location, there are other ways we can attempt to cope with weather and climate change and its consequences for different forms of activities (Dunne *et al*, 2013). Conditions may be altered not only by individual weather events but also by sequences of weather events. Continuous record of data sequences, plays a big role in determining stream runoff and soil moisture, and can result in prolonged periods of abnormal temperatures and sunshine. As explained by Eltahir *et al* (2015), the important determinants of construction productivity and the responsiveness of other inputs as motivation depends on the growing conditions supplied by a sequence of weather events. Runoff to surface streams and groundwater recharge, or replenishment, depends on extended sequences of weather events. In addition, the timing of runoff in mountainous river basins is strongly dependent on snowpack accumulation and rate of melt. Mountain runoff, thus, is quite sensitive to temperature variations. The quantity and timing of runoff, in turn, determine the availability of water for construction, agricultural, municipal, industrial, hydropower, recreational, and ecological uses.

Severe Weather Events

The most dramatic impact of weather on human endeavors is often through severe weather events that may differ as the climate changes (Akinbode *et al*, 2011). Severe weather has always affected human activities and settlements as well as the physical environment in general. It can damage property, cause loss of life and population displacement, destroy or sharply reduce agricultural crop yields, and temporarily disrupt essential services such as transportation, telecommunications, energy and water supplies. Society has developed various methods to avoid or minimize adverse impacts of weather and has also developed means to facilitate recovery from extreme weather phenomena. As severe weather events repeatedly disrupt socioeconomic activities and cause damage, society continues to search for new ways to protect lives and property (Akinbode *et al*, 2011). One way of reducing vulnerability to weather is to increase construction of buildings, reduce damage to property, standard compliance on construction, tighter building codes, and restrictions on development in flood prone areas and on coastal barrier islands. The construction of storm sewers can help minimize short-term flood damage in highly developed areas where there is substantial impermeable surface such as pavement. The casualty and hazard insurance industry in more developed countries helps insured parties to rebuild and replace property damaged by severe weather.

Weather and Season

The term weather describes the prevailing geographical characteristics of a specific region regarding climate and other aspects that define the atmosphere such as humidity and temperature among others which is caused by earth movements and changes in atmospheric conditions. The term weather describes the immediate change of climatic conditions in a specific region with time which is usually measured within short periods in hours or days. Some of the factors used to measure weather of a specific geographical position include humidity, speed of wind at a given time and temperature, (Crissinger *et al* 2015).

The term season can be described as changes in weather and climatic condition that are caused by the revolution of the earth around the sun. When the earth moves round the sun, some part of it face away from the sun making them experience winter while those the part that faces the sun experience hot airs causing changes in climatic conditions. Weather means the daily temperature, precipitation, winds, and the amount of the sunshine that hits the earth surface. While, season can be used to describe general condition of weather in a specific region which takes an average period of three months (Smith, and Katz, 2013).

The period at which weather and season last in a specific geographical location varies with time. Weather conditions are described as daily patterns of temperature, humidity, and wind. However, these patterns are likely to change within few hours or last for several days. On the other hand, a season lasts for more than three months where a region experiences a combination of several weather patterns which may include high temperatures and dry winds with low humidity to ice regions. Seasons are known to last for three to four months. Similar characteristics can be seen on plants which shed their leaves during summer to prevent water shortage and flower during the spring season when there are enough rain and sunshine to support their activities (Niemela *et al.*, 2012).

According to Kalkstein *et al* (2013), weather changes at a short distance where one is likely to experience different atmospheric conditions in two areas which are several miles apart. For example, a city can be experiencing heavy rainfall while the outskirts of the city which are less than ten miles away are experiencing cold winds with no rain. A season covers a large and a wide area of many miles experiencing similar weather patterns.

Effects of Weather on Productivity

Weather has many effects on worker productivity. According to Olomolaiye *et al* (2017) weather condition contributes to employees' productivity, quality output, level of wastage and rate of turnover. He further stated that unhealthy depressing and unsafe work environment leads to job dissatisfaction and eventually low productivity. Akinbode *et al.*, (2018) opined that safety measures are important in every organization to reduce the effect on worker, thereby improving productivity and effectiveness. Akinbode *et al.*, (2018) further stated that, many people are not only interested on the pay when seeking for job, but also want good working conditions which includes the good weather condition, health

and safety working environment. In addition, he stated that high weather condition, inadequacy of first aid box, lack of provision of safety kits in the work place will affect employees negatively. He further emphasized that the morale interest and attitude of workers will not be boosted if they understand that they are not cared for.

Construction projects, in general, are executed in an outdoor environment, and therefore are affected by weather conditions. Weather impact was reported to be one of the main factors causing delay and cost overruns on construction projects delivery (Baldwin et al. 2011; Koehn and Meilhede 2011). Considerable numbers of construction activities are sensitive to weather conditions. Benjamin et al. (2013) suggested that almost 50% of construction activities are sensitive to weather conditions. The impact of weather on construction activities can be in the form of reduced labor productivity, poor performance, and work stoppage. Reduced labor productivity is generally attributed to reduced human performance due to heat or cold stresses resulting from the combined effect of temperature, humidity, and wind velocity. However, weather impact is quantified based on either an industry-wide average performance on general construction work or industry-specific performance on specialized work, which includes electrical work, masonry work, general manual tasks, and equipment tasks.

Research Methodology

The methodology adopted for this paper involved the selection of different building operation which include manual excavation, blockwork and plastering. Different factors were considered for each trade and the sites visited in Jos were met at different stages of activities when the study was conducted. It was assumed that all the skill labour observed had trade permit, required and adequate experience and also the support unskilled labourers were assumed to have the same common capability, strength and experience. The data were generated through direct observation of workers and the usage of watch on sites were categorized according to output per day, number of crew per operations, weather and climatic conditions as presented on table 1-4. The sampled sites were visited daily in order to observe labour productivity and to reduce ambiguity in result presented, to have actual and factual information to be provided and for error to be minimized. This process has ensured enhancement in quality of work and improvement on the productivity level of workers as they are aware that they are directly observed. Population of the study comprised of 196 skilled and unskilled labor which were sampled through random stratified sampling method, with 25 construction sites visited in Jos. The reason behind Stratified sampling is that it represents particular characteristics of the population which the researcher believes to have experience on a particular event in view (Kothari, 2004). The choice of Jos is influenced by the fact that the area is really affected by change in weather and majority of small and medium scale construction firms are having on-going building construction on every part of the metropolis. SPSS was used for the analysis: to run multiple regression and percentages (descriptive statistics) to analyze the data obtained. The

outputs of workers were calculated, taken into consideration the time taken to execute a specific task and the quantity of work done per operation within the observed time.

$$\text{Percentage Difference (\%)} = \frac{\text{maximum value} - \text{minimum value}}{\text{maximum value}} \times 100$$

Result and Discussion

The study followed a detailed daily collection of productivity of workers for the selected trades on construction site during the study period due to temperature, wind speed, and humidity as presented in table 1-4. It is worth noting that construction productivity is not only affected by the weather, but also by other variables such as mental state of labors, sudden accidents, and shortage of materials. However, this study focuses deals on weather conditions which have direct impact on the construction workers and this in turn have influence on project productivity and delivery.

Figure 1 shows the impact of temperature on the productivity of manual excavation during dry weather, the histogram indicates temperature level while frequency curve show productivity of manual excavation output. It can be seen that output of manual excavation was low due to negative impact of temperature during the month of march and April. With dry weather temperature intensity on the soil is high and it makes the soil to be very hard on manual excavation. For instance, from table 1, the manual excavation productivity reached the minimum value of 8m³/ crew/day on Thursday, 08/04/2021. and reached maximum value of 12m³/crew/day on Saturday, 10/04/2021. The percentage difference between the minimum and maximum productivity values is 33.33%, this however shows that weather have significant impact on the productivity of workers.

Figure 2 shows the impact of temperature on productivity of block work during dry weather. The output of the regression standardized residual shows high productivity of block work was high as shown from the flow of histogram and frequency curve. The implication from graphical illustration shows that temperature impact on productivity of block work was positive during the months of March and April. However, the block work productivity reached the minimum value of 22m²/ crew/day on Saturday, 03/04/2021, and reached the maximum value of 50.2m²/crew/day on Wednesday, 14/04/2021. The percentage difference between the minimum and maximum productivity values is 56.3%.

Figure 3 shows the impact of temperature on the productivity of plastering during dry weather, the result demonstrates large increase in plaster work productivity during the dry weather. Furthermore, the plastering/rendering productivity reached the minimum value of 18.3m²/ crew/day on Monday, 05/04/2021. On the other hand, it reached the maximum value of 47m²/crew/day on Saturday, 24/04/2021. The percentage difference between the minimum and maximum productivity values is 61%.

Figure 4 shows multiple bar chats of the impact of relative humidity impact on productivity of manual excavation, Block Work and Plastering. From the figure it shows that relative humidity has no impact on productivity of block work, plastering and manual excavation in March and April as worker averagely performed during this period.

Figure 5 shows the impact of wind speed on construction worker's productivity during dry weather. The indicators further explained that wind speed has no effect on productivity of manual excavation, block work and plastering during the month of March and April as worker performed on an average scale.

From the above, the temperature impact negatively on manual excavation during dry weather condition, the temperature intensity on the soil is high and it makes the soil to be very hard. The temperature intensity which is high increases heat intensity and this makes the body weak easily. However, this is opposite to block work and plaster operation during this period as there is high productivity during this period as compared to manual excavation which requires more energy during its operation. Although, the output of mason is not very high in this period but on an average scale the mason performs better. As temperature of the increases it leads to body dehydration and the worker are exposed to intense hot weather. In general, as the site temperature increases, the output of workers reduces for all operation but significantly reduced for manual exaction operation. Furthermore, relative humidity and wind speed have very low effect on productivity of manual excavation, block work and plastering during dry weather. This study is in line with previous researchers of Zhou, et al., (2015); Oladapo (2017); Randa et al. (2019) who in their various studies revealed that the productivity of manual excavation is low during the summer weather while ceramic work, block work and plaster work productivity increases.

Figure 6 shows the impact of temperature on productivity of manual excavation during wet weather (June and July). The graphic illustration revealed that temperature intensity had no negative impact on productivity of manual excavation due to wet soil. Therefore, the productivity of manual excavation is high. For instance, the manual excavation productivity reached the minimum value of 8.4 m³/ crew/day on Friday, 18/06/2021 and reached maximum value of 20 m³/crew/day on Monday, 05/07/2021. The percentage difference between the minimum and maximum productivity values is 58%.

Figure 7 shows the impact of temperature on block work productivity during wet weather. This result revealed that the intensity of temperature on productivity of block work has negative impact on block work output due to the large down pour of rainfall in the study area. Rainfall during the months of June and July do interrupt work on site and this have significant effect on block work productivity at this period as the moment rain start, it will be difficult for mortar mix to be prepared as majority of work is carried out in outdoor environment situations, also it is difficult for craftsmen to carry out activities when there is heavy rainfall. Throughout the period when it rains work is put on hold until after the rain. In addition, rainfall in Jos, plateau state from measurement during this period take about 5 hours continues rainfall in minimum. However, block work productivity reached minimum value of 29.7 m²/ crew/day on Thursday, 01/07/2021 and reached maximum value of 49.5m²/crew/day on Saturday, 21/06/2021. The percentage difference between minimum and maximum productivity values is 40% which is low on an average scale.

Figure 8 shows the impact of temperature on plastering productivity during wet weather. The result shows that wet weather has negative impact on productivity of plastering. Plastering dry very slowly during wet weather than dry weather. This result also indicated that the productivity of plastering during the month of June and July was low. For instance, the plastering/rendering productivity reached the minimum value of 19 m²/ crew/day on Thursday, 10/06/2021 and reached maximum value of 36 m²/crew/day on Saturday, 10/07/2021. The percentage difference between the minimum and maximum productivity values is 47% which low on an average scale.

Figure 9 shows the results on the impact of wet weather on productivity of manual excavation, block work and plastering based on relative humidity. The figure shows that relative humidity had no impact on productivity of manual excavation, block work and plastering during wet weather.

Figure 10 shows the impact of wind speed on productivity of manual excavation, block work and plastering during wet weather. The figure indicated that wind speed has positive impact on productivity of manual excavation, block work and plastering.

From the above, temperature impact negatively on block work and plastering but have positive impact on manual excavation. At this period the soil is soft and have minimal dust rising from it which makes works easier. Worker develop good morale due to good weather, but high and frequent rainfall affects worker's productivity, this season also prevent plaster from drying on time as reported during the study. Also, the study finds out that there is no effect of relative humidity and wind speed on productivity of manual excavation, block work and plastering during rainy weather condition. This finding is in agreement with that of Mohammed Al-Abbasi (2014) who found that the productivity of manual excavation increases during the summer weather while ceramic work, block work and plaster work productivity decreases. The findings of this study is contrary to that of Olsen et al. (2012) who found that relative humidity and wind speed has effects on productivity of manual excavation, block work and plastering during wet weather condition.

Table 4 shows the percentage productivity difference of three trades namely; manual excavation, block work and plastering during the dry and rainy weather condition. the result shows the three trade percentage productivity difference during the dry and rainy weather condition. The manual excavation during dry weather condition constitute 33%, block work 56.3% and plastering work 61% respectively, while during wet weather the percentage productivity difference are; manual excavation 58%, block work 40% and plastering 47% respectively.

The study also shows that temperature have negative impact on productivity of manual excavation during dry weather condition. Using multiple regression in testing productivity of manual excavation, block work and plastering, the output revealed that relative humidity and wind speed has no effect on the operations of the trade. This finding is in agreement with that of Ndiokubwayo (2018); Ayoade (2013); Rodwell and Haskins (2016) who found

that temperature has the strongest impact on trade productivities, while wind speed and humidity have a lower impact on trade productivities.

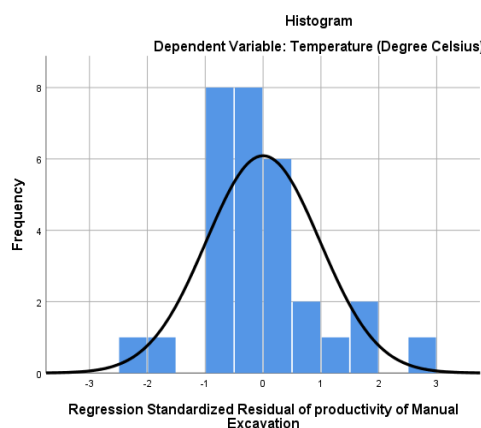


Figure 1: Temperature against productivity of manual excavation. **March/April.**

Source: Author (2021)

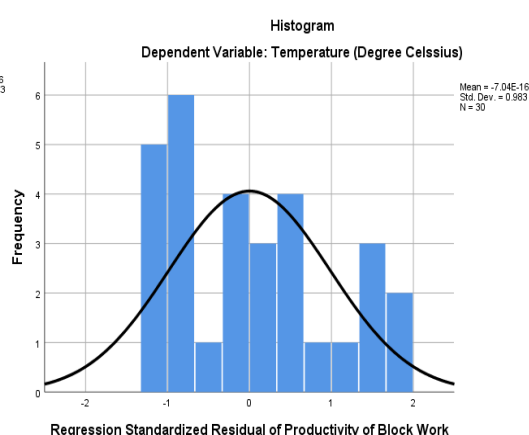


Figure 2: Temperature against productivity of block work. **March/April.**

Source: Author (2021)

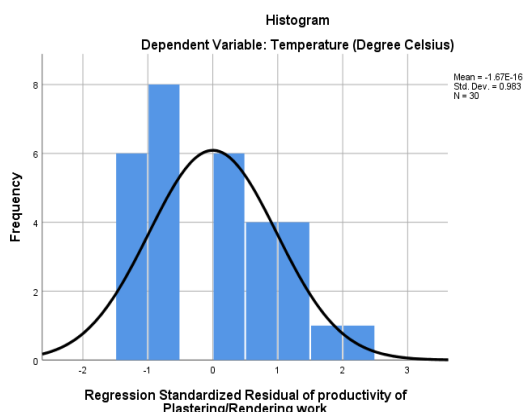


Figure 3: Temperature against productivity of plastering work. **March/April.**

Source: Author (2021)

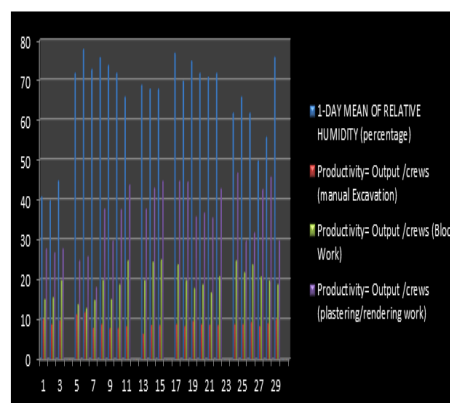


Figure 4: Relative humidity against productivity of manual excavation, block work and plastering work. **March/April.**

Source: Author (2021)

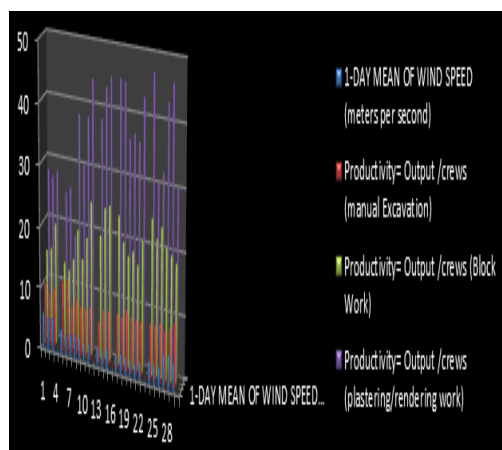


Figure 5: Wind speed against productivity of manual excavation, block work and plastering work. **March/April.**

Source: Author (2021)

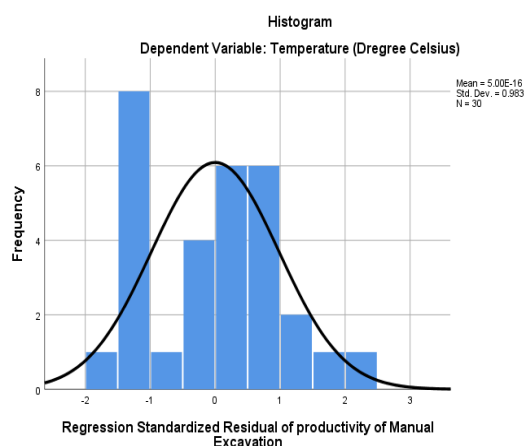


Figure 6: Temperature against productivity of manual excavation. **June/July.**

Source: Author (2021)

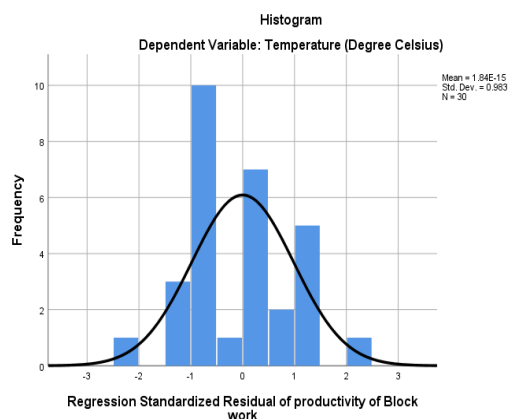


Figure 7: Temperature against productivity of block work. **June/July.**

Source: Author (2021)

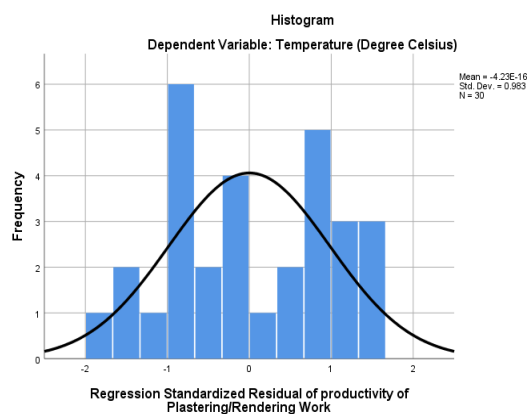


Figure 8: Temperature against productivity of plastering work. **June/July.**

Source: Author (2021)

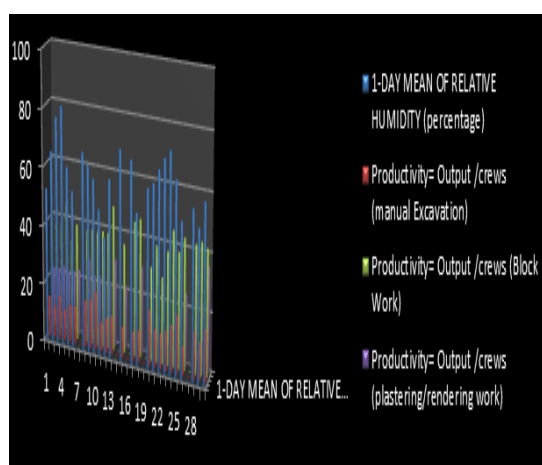


Figure 9: Relative humidity against productivity of manual excavation, block work and plastering work. **June/July.**

Source: Author (2021)

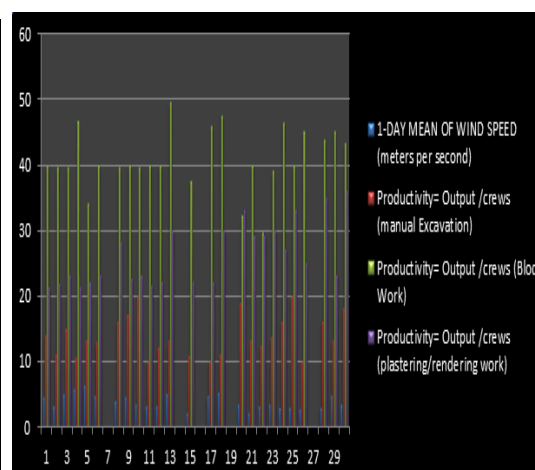


Figure 10: Wind speed against productivity of manual excavation, block work and plastering work. **June/July.**

Source: Author (2021)

Conclusion

Temperature has significantly impact negatively on manual excavation during dry weather condition, but positively impact on block work and plastering operation during dry weather condition. Also, during wet weather condition temperature negatively affect blockwork and plastering operations, this is in contrast as temperature positively impact manual excavation operation during wet season. The reduction in the output of workers during manual excavation in dry season is as a result of intense heat which make the soil hard and dusty, the intense heat during dry season lead to dehydration which weakens energy and ability to carry out activities effectively, the dust when inhale in high quantity might lead to breathing problem. However, it can also be deduced that the higher the labour force the higher the productivity of the workers. During wet weather, the frequent pour of rainfall affects the worker's ability to perform efficiently, plaster during this period dry very slowly, block work is affected by rainfall as rain washes the mortar mix in walling and also prevent mix when the weather changes as its about to rain which affect working time and generally productivity of workers. In essence, the impact of temperature in the Jos on the daily productivity of workers during the period of dry weather was significant for manual excavation operations, while the effect was also significant blockwork and plaster operation during the wet weather in the two periods examined.

Recommendations

1. Contractor needs to consider the effects of weather condition on construction activity duration during schedule of projects in Jos.

2. There is a need for construction managers to find ways to reduce the impact of temperature on the job site such as using temporary shades or spreading cold water if required.
3. Awareness on factors which lead which contribute to weather changes need to be considered to ensure project are delivered with the required quality, on time and within budget.
4. Machineries should be set up to complement intensive work adverse harsh conditions on site.
5. There is need for the provision of helmets and overall coats and rain coats that reduce sun radiation to prevent harsh sunny period, sun burns, and heavy rainfall.

Recommendations for Further Studies

1. Further Research should be carried out on the effect of weather change on cost and time performance of project.
2. Further research should be carried out impact of secondary data (meteorological data) on the project planning implementation.
3. Further Research should be carried out on the effect of weather change on quality service delivery of project.
4. Future research should focus on developing relationships between weather variables and trade productivity.
5. Future research should be carried out on simulation-based approach for weather change to trade application to enhance productivity, properly plan for weather changes in a more systematic way and monitor trades in a comprehensive way.

References

- Andrews, W.A., (2015): Understanding Global Warming.
- Aderinto, S.A. (2016). Implication of Automatic Weather Observing Stations in Nigerian Meteorological Agency, Unpublished IMO report. Ileoje NP. 2001. A New Geography of Nigeria, New Revised Edition. Longman Publishers: Ibadan, Nigeria.
- Akinbode, O.M., Eludoyin, A.O. and Fashae, O.A. (2018) Temperature and relative humidity distributions in a medium-size administrative town in southwest Nigeria, Journal of Environmental Management.
- Baldwin, J.R., Manthei, J.M., Rothbart, H., and Harris, R.B. (2017). Causes of delay in the construction industry. ASCE Journal of the Construction Division.
- Benjamin, N.B.H., and Greenwald, T.W. (2017). Simulating effects of weather on construction. ASCE Journal of the Construction Division.
- Borcherding, J. D., and Liou, F.-S. (2016). "Work sampling can predict unit rate productivity." Journal of Construction Engineering and Management, 112(1), 90- 103.
- Brodoli, D. (2010). 'Weather Claims in the United Kingdom Construction Industry'. [Online]. Available at: <http://www.driver-group.com/~media/Files/D/DriverGroup/Attachments/news-and-article/weather-claims-in-uk-construction.pdf>.

- Biparva, A. (2010). 'How Weather Creates Challenges for the Construction Industry'. [Online]. Available at: <http://blog.kryton.com/2010/07/hot-weather-creates-challenges-for-construction-industry/> [Accessed on: 25 February 2021].
- Crissinger, J. (2015). 'Design and Construction vs Weather'. [Online]. Available at: <http://www.rcionline.org/interface-articles-2005.html> [Accessed on: 12 March 2021].
- Dunne J.P., Stouffer R.J., and John J.G. (2013), Reductions in labour capacity from heat stress under climate warming. National. Climate. Change.
- Eltahir, E. A. B. and Gong, C. (2015). "Dynamics of Wet and Dry Years in West Africa", Journal of Climate.
- Mills, (2013). Winter mortality in a warming climate: a reassessment. WIREs Climate Change.
- Niemela", Raimo, Mika-Hannula, Sari-Rautio, Kari-Reijula, and Jorma-Railio. (2012), The effect of air temperature on labour productivity a case study of Energy and Buildings.
- Kalkstein, L. and Smoyer, K. (2013) The impact of climate change on human health: some international implications Cellular and Molecular Life Sciences.
- Koehn, E., and Brown, G. (2015). "Climatic effects on construction." Journal of Construction Engineering and Management.
- Olomolaiye, P. O., Wahab, K., and Price, A. (2017). "Problems influencing craftsman productivity in Nigeria." Building Environment.
- Smith, G.R., and Hancher, D.E. (2019). Estimating precipitation impacts for scheduling. ASCE Journal of Construction Engineering and Management,
- Sumanth, D. J. (2014). Productivity Engineering and Management.
- Umaru, D., and Yaquib, J.O (2013). Labour Productivity and Health Capital in Nigeria: The Empirical Evidence. International Journal of Humanities and Social Sciences.Vol.3 No.4.

Appendix

Table 2: Daily Operation and Productivity for the month of March and April

S/N	PROJECT	Date	OPERATION	No of	Number of		Productivity	Date	OPERATION	No of	No of	working	Prod.
	LOCATION			Workers	Crews	Hours	output			Workers	Crews	Hours	output
1	Jos	29/3/2021	Manual Exc.	8	4	8	41 m ³	29/3/2021	Block Work.	8	4	8	61 m ²
2	Jos	30/3/2021	Manual Exc.	8	4	9	36 m ³	29/3/2021	Block Work.	8	4	9	63 m ²
3	Jos	31/3/2021	Manual Exc.	6	3	8	30 m ³	29/3/2021	Block Work.	6	3	8	60 m ²
4	Jos	2/4/2021	Manual Exc.	8	4	8	46 m ³	2/4/2021	Block Work.	8	4	8	56 m ²
5	Jos	3/4/2021	Manual Exc.	8	4	8	48 m ³	3/4/2021	Block Work.	8	4	8	52 m ²
6	Jos	5/4/2021	Manual Exc.	8	4	8	32 m ³	5/4/2021	Block Work.	6	3	10	45 m ²
7	Jos	6/4/2021	Manual Exc.	8	4	8	36 m ³	6/4/2021	Block Work.	8	4	9	80 m ²
8	Jos	7/4/2021	Manual Exc.	8	4	8	32 m ³	7/4/2021	Block Work.	8	4	8	61 m ²
9	Jos	8/4/2021	Manual Exc.	7	3	8	24 m ³	8/4/2021	Block Work.	8	4	9	76 m ²
10	Jos	9/4/2021	Manual Exc.	8	4	8	34 m ³	9/4/2021	Block Work.	8	4	8	100 m ²
11	Jos	12/4/2021	Manual Exc.	7	4	6	26.4 m ³	12/4/2021	Block Work.	8	4	8	80 m ²
12	Jos	13/4/2021	Manual Exc.	8	4	8	35 m ³	13/4/2021	Block Work.	8	4	8	98.4 m ²
13	Jos	14/4/2021	Manual Exc.	8	4	8	35 m ³	14/4/2021	Block Work.	8	4	8	100.8 m ²
14	Jos	16/4/2021	Manual Exc.	6	3	6	27 m ³	16/4/2021	Block Work.	8	4	8	96 m ²
15	Jos	17/4/2021	Manual Exc.	10	5	8	42.5 m ³	17/4/2021	Block Work.	8	4	9	80 m ²
16	Jos	19/4/2021	Manual Exc.	8	4	8	39.2 m ³	19/4/2021	Block Work.	8	4	9	72 m ²
17	Jos	20/4/2021	Manual Exc.	7	4	8	36 m ³	20/4/2021	Block Work.	8	4	9	76 m ²
18	Jos	21/4/2021	Manual Exc.	8	4	8	35.6 m ³	21/4/2021	Block Work.	8	4	9	68 m ²
19	Jos	22/4/2021	Manual Exc.	8	4	8	35 m ³	22/4/2021	Block Work.	8	4	8	84 m ²
20	Jos	24/4/2021	Manual Exc.	8	4	8	27 m ³	24/4/2021	Block Work.	8	4	8	41 m ²
21	Jos	26/4/2021	Manual Exc.	6	3	6	27 m ³	26/4/2021	Block Work.	8	4	8	41 m ²
22	Jos	27/4/2021	Manual Exc.	8	4	8	38 m ³	27/4/2021	Block Work.	8	4	8	41 m ²
23	Jos	28/4/2021	Manual Exc.	8	4	8	34 m ³	28/4/2021	Block Work.	8	4	8	41 m ²
24	Jos	29/4/2021	Manual Exc.	8	4	8	37 m ³	29/4/2021	Block Work.	8	4	8	41 m ²
25	Jos	30/4/2021	Manual Exc.	8	4	8	41 m ³	30/4/2021	Block Work.	8	4	8	41 m ²
26	Jos	29/3/2021	Plastering	8	4	8	112 m ²	16/4/2021	Plastering	8	4	8	180 m ²
27	Jos	30/3/2021	Plastering	8	4	8	108 m ²	17/4/2021	Plastering	14	7	8	313.25 m ²
28	Jos	31/3/2021	Plastering	6	3	9	112 m ²	19/4/2021	Plastering	6	3	8	108 m ²
29	Jos	2/4/2021	Plastering	8	4	8	150 m ²	20/4/2021	Plastering	12	6	8	222 m ²
30	Jos	3/4/2021	Plastering	6	3	0	78 m ²	21/4/2021	Plastering	8	4	8	143 m ²
31	Jos	5/4/2021	Plastering	8	4	8	73.2 m ²	22/4/2021	Plastering	7	4	8	172 m ²
32	Jos	6/4/2021	Plastering	8	4	10	152 m ²	24/4/2021	Plastering	8	4	8	188 m ²
33	Jos	7/4/2021	Plastering	12	6	8	180 m ²	26/4/2021	Plastering	12	6	8	180 m ²
34	Jos	8/4/2021	Plastering	8	4	8	151.28 m ²	27/4/2021	Plastering	6	3	8	96 m ²
35	Jos	9/4/2021	Plastering	8	4	8	176 m ²	28/4/2021	Plastering	8	4	8	171.56 m ²
36	Jos	12/4/2021	Plastering	6	3	8	152 m ²	29/4/2021	Plastering	6	3	8	138 m ²
37	Jos	13/4/2021	Plastering	8	4	8	172.8 m ²	30/4/2021	Plastering	8	4	8	120 m ²
38	Jos	14/4/2021	Plastering	6	3	8	135 m ²						

Table 3: Daily Operation and Productivity for the month of June and July

S/N	PROJECT	Date	OPERATION	No of	Number ofworkings			Productivity	Date	OPERATION	No of	No of	workings	Prod.	
LOCATION				Workers	Crews	Hours	output					Workers	Crews	Hours	output
1	Jos	7/6/2021	Manual Exc.	7	4	6	56 m³	7/6/2021	Block Work.	8	4	8	159 m²		
2	Jos	8/6/2021	Manual Exc.	8	4	8	44 m³	8/6/2021	Block Work.	8	4	8	158 m²		
3	Jos	9/6/2021	Manual Exc.	8	4	8	60 m³	9/6/2021	Block Work.	6	3	9	199 m²		
4	Jos	10/6/2021	Manual Exc.	8	4	8	42 m³	10/6/2021	Block Work.	8	4	8	187 m²		
5	Jos	11/6/2021	Manual Exc.	8	4	8	52 m³	11/6/2021	Block Work.	6	3	8	102 m²		
6	Jos	12/6/2021	Manual Exc.	10	5	8	64.45 m³	12/6/2021	Block Work.	8	4	8	160 m²		
7	Jos	15/6/2021	Manual Exc.	8	4	8	64 m³	15/6/2021	Block Work.	8	4	8	158 m²		
8	Jos	16/6/2021	Manual Exc.	8	4	8	68 m³	16/6/2021	Block Work.	7	4	8	160 m²		
9	Jos	17/6/2021	Manual Exc.	8	4	8	80 m³	17/6/2021	Block Work.	8	4	8	158 m²		
10	Jos	18/6/2021	Manual Exc.	8	4	8	33.6 m³	18/6/2021	Block Work.	8	4	8	160 m²		
11	Jos	19/6/2021	Manual Exc.	8	4	8	48 m³	19/6/2021	Block Work.	8	4	8	160 m²		
12	Jos	21/6/2021	Manual Exc.	10	5	8	65 m³	21/6/2021	Block Work.	7	4	6	198 m²		
13	Jos	23/6/2021	Manual Exc.	8	4	8	43 m³	23/6/2021	Block Work.	8	4	8	150 m²		
14	Jos	25/6/2021	Manual Exc.	6	3	8	30 m³	25/6/2021	Block Work.	6	3	8	138 m²		
15	Jos	26/6/2021	Manual Exc.	8	4	8	44 m³	26/6/2021	Block Work.	8	4	8	190 m²		
16	Jos	29/6/2021	Manual Exc.	8	4	8	76 m³	29/6/2021	Block Work.	7	4	7	129 m²		
17	Jos	30/6/2021	Manual Exc.	8	4	8	52 m³	30/6/2021	Block Work.	8	4	8	160 m²		
18	Jos	1/7/2021	Manual Exc.	8	4	8	48.8 m³	1/7/2021	Block Work.	8	4	8	118.8 m²		
19	Jos	2/7/2021	Manual Exc.	8	4	9	54 m³	2/7/2021	Block Work.	10	5	8	195 m²		
20	Jos	3/7/2021	Manual Exc.	8	4	8	64 m³	3/7/2021	Block Work.	8	4	8	186 m²		
21	Jos	5/7/2021	Manual Exc.	6	3	8	60 m³	5/7/2021	Block Work.	8	4	6	159 m²		
22	Jos	6/7/2021	Manual Exc.	8	4	8	40 m³	6/7/2021	Block Work.	8	4	8	180 m²		
23	Jos	8/7/2021	Manual Exc.	8	4	9	60 m³	8/7/2021	Block Work.	8	4	8	175 m²		
24	Jos	9/7/2021	Manual Exc.	8	4	9	52 m³	9/7/2021	Block Work.	8	4	8	180 m²		
25	Jos	10/7/2021	Manual Exc.	8	4	8	72 m²	10/7/2021	Block Work.	8	4	8	173 m²		
26	Jos	7/6/2021	Plastering	8	4	8	85 m²	23/6/2021	Plastering	7	7	8	88 m²		
27	Jos	8/6/2021	Plastering	8	4	8	87 m²	25/6/2021	Plastering	4	3	8	88 m²		
28	Jos	9/6/2021	Plastering	6	3	8	69 m²	26/6/2021	Plastering	8	6	8	120 m²		
29	Jos	10/6/2021	Plastering	4	4	8	84.8 m²	29/6/2021	Plastering	6	4	8	99 m²		
30	Jos	11/6/2021	Plastering	8	4	8	88 m²	30/6/2021	Plastering	6	4	8	87 m²		
31	Jos	12/6/2021	Plastering	6	3	8	69 m²	1/7/2021	Plastering	8	4	8	116 m²		
32	Jos	15/6/2021	Plastering	8	4	8	112 m²	2/7/2021	Plastering	12	6	8	180 m²		
33	Jos	16/6/2021	Plastering	8	4	8	90 m²	3/7/2021	Plastering	14	3	8	189 m²		
34	Jos	17/6/2021	Plastering	6	3	8	69 m²	5/7/2021	Plastering	6	4	8	99 m²		
35	Jos	18/6/2021	Plastering	8	4	8	86 m²	6/7/2021	Plastering	6	3	8	75 m²		
36	Jos	19/6/2021	Plastering	8	4	8	88 m²	8/7/2021	Plastering	8	4	8	140 m²		
37	Jos	21/6/2021	Plastering	6	3	8	90 m²	9/7/2021	Plastering	8	4	8	92 m²		
38	Jos	10/7/2021	Plastering	8	4	8	144 m²								

Table 4: Weather condition for the study period

S/N	PROJECT	Date	Mean Temp.	Mean W.S	Mean R.H	Date	Mean Temp.	Mean W. S	Mean R.H
1.	Jos	7/6/2021	30	4.5	53	7/6/2021	30	4.5	53
2.	Jos	8/6/2021	30	3.2	66	8/6/2021	30	3.2	66
3.	Jos	9/6/2021	28	4.9	78	9/6/2021	28	4.9	78
4.	Jos	10/6/2021	31	5.7	82	10/6/2021	31	5.7	82
5.	Jos	11/6/2021	28	6.2	62	11/6/2021	28	6.2	62
6.	Jos	12/6/2021	29	4.6	54	12/6/2021	29	4.6	54
7.	Jos	15/6/2021	28	3.9	68	15/6/2021	28	3.9	68
8.	Jos	16/6/2021	31	4.5	64	16/6/2021	31	4.5	64
9.	Jos	17/6/2021	27	3.4	60	17/6/2021	27	3.4	60
10.	Jos	18/6/2021	31	3.0	50	18/6/2021	31	3.0	50
11.	Jos	19/6/2021	27	3.1	41	19/6/2021	27	3.1	41
12.	Jos	21/3/2021	26	5.0	61	21/3/2021	26	5.0	61
13.	Jos	23/6/2021	27	2.0	72	23/6/2021	27	2.0	72
14.	Jos	25/6/2021	29	4.7	69	25/6/2021	29	4.7	69
15.	Jos	26/6/2021	28	5.2	52	26/6/2021	28	5.2	52
16.	Jos	29/6/2021	26	3.4	61	29/6/2021	26	3.4	61
17.	Jos	30/6/2021	28	2.2	63	30/6/2021	28	2.2	63
18.	Jos	1/7/2021	28	3.0	68	1/7/2021	28	3.0	68
19.	Jos	2/7/2021	28	3.4	72	2/7/2021	28	3.4	72
20.	Jos	3/7/2021	27	2.8	75	3/7/2021	27	2.8	75
21.	Jos	5/7/2021	25	2.9	66	5/7/2021	25	2.9	66
22.	Jos	6/7/2021	27	2.7	53	6/7/2021	27	2.7	53
23.	Jos	8/7/2021	26	2.9	58	8/7/2021	26	2.9	58
24.	Jos	9/7/2021	27	4.6	66	9/7/2021	27	4.6	66
25.	Jos	10/7/2021	26	3.4	61	10/7/2021	26	3.4	61

Temp = Temperature

W.S = Wind Speed

R.H = Relative Speed