FORCASTING LOW HORIZONTAL VISIBILITY IN MURTALA MUHAMMED AIRPORT, IKEJA, LAGOS, NIGERIA

BY

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ABSTRACT

Air transport is recognized worldwide as the quickest, safest and most reliable means of movement from continent to another. Although aviation is the leading sector in transportation it still has some challenges to overcome. Air transportation calls for a need to understand the atmosphere as it significantly affects its operation; hence the undisputable need of meteorology (a branch of science dealing with the earth's atmosphere and the physical processes occurring in it) in aviation. Weather affects aviation operations and could be improved upon by monitoring and understanding the relationship of weather variables. Accurate weather observation is very important for it is the back-bone of weather forecasting as present weather records serves as input variables upon which forecast models are built, hence accurate reports should be made. Weather forecasting is of paramount importance in aviation operation at MurtalaMuhammed International Airport. This research is aim at generating a technique that will aid in predicting low visibility at the airport. The result shows that four major weather conditions account for the occurrence of low visibility. They are haze, rain, fog and mist. Result of correlation analysis reveals that development of these weather conditions are favoured by two major causative factors which are relative humidity (RH) and dew point temperature. Days of high RH tends to bring about low visibility while reduction in dew point temperature favour low visibility occurrence. Hence, it is reasonable to conclude on the effectiveness of using these two causative factors in developing predictive model for low visibilityIn order to get accurate forecast of low visibility in the study area it is of paramount important to also consider values of dew point temperature and relative humidity as they are the main causative factors of low visibility in the airport. The use of models such as multilayer perceptron which uses artificial intelligence to learn and recognise pattern should be employ in weather forecasting. . Multilayer Perceptron (MLP) and multiple linear regression analysis are the two predictive model used and it shows that MLP generated a model which is good for predicting low visibility for haze, fog and mist conditions while Multiple Linear Regression model is good for predicting low visibility during low visibility on rainy conditions. Although from the result it showed that it MLP behaves poorly during rainy conditions compare to regression model, therefore forecasters should not rely on just one model but should employ the use of different models in low visibility forecasting.

Key words: Visibility, aviation, weather, forecast, multilayer perceptron.

1.0 INTRODUCTION

Ever since the existence of man, movement has been part of our need. It is a basic characteristic of man. The extent of area covered differed as the need arises. Many means of transportation had been adopted ranging from animal riding to chart, canoe, boat, automobile, locomotives among many others. Transportation by air being the latest means has proven to be the fastest, most efficient means as it is time saving and covers large geographical field. Advancement in transportation means came by a need to overcome the deficiencies in older means of transportation.
Transporting in air calls for a need to understand the atmosphere as it significantly affects its operation; hence the undisputable need of meteorology.Weather is an important factor that influences aircraft performance and flying safety. It is the state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind, visibility, and barometric pressure (high or low). The term weather can also apply to adverse or destructive atmospheric conditions, such as high winds.

Poor visibility is the single most important weather hazard to all forms of transportation especially air transportation. (Ayoade, 2004). Poor visibility is perhaps a greater danger to safe plane landing because the control over it is more difficult than flooding on the runway. Poor visibility can be caused by thick fog, snow, rain, thunderstorm, harmattan dust, mist, volcanic ash or smoke, urban smoke, low ceiling or even smog. Clearly during low visibility, it is difficult to operate in airport especially during taxi in and out, pilots taxi at slower rate with more caution and less accurate awareness. Anthony,(1995)

In January and December (2005), early morning fog was reported in: Lagos, Port Harcourt, Owerri and Jos which reduced horizontal visibility to between 200-800m. This resulted in flight delays at these airports. Despite the relatively conducive weather of Nigeria compared to other countries, there has been marked increase in the cases of recorded flight delay, diversion and cancellation, which in most cases, are attributed to poor weather conditions. The Sosoliso plane crash in 2006 was partly caused by poor visibility because of thunderstorm and rain when trying to land in Port Harcourt airport (Ayoade, 2004).In Murtala Muhammed Airport and revealed that fog accounted for 13.2% of flight cancellation at the airport and line squall similarly accounted for 10.1% of delays, 8.4% of diversion and 20% of cancellation from 2000-2009 at the airport. (Weli *and* fediba, 2013).According to them the

growth of aviation industry in Nigeria and the increased adoption of air transportation as one of the best means of transport have been obstructed by various weather hazards. There is a greater need for aviation weather forecasters to deliver quality forecasts. It is therefore necessary to identify the most dangerous and most common weather hazards which are detrimental to the aviation industry so as to enhance the expertise on addressing them.
Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location. Human have attempted to predict the weather informally for millennia, and formally since at least the nineteenth century. Weather forecasts are made by observing and collecting qualitative and quantitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve (Mark *et al*., 2016**).** According to Mark *et al*., 2016 various techniques are used in predicting various weather patterns depending on the desired parameter to forecast. Techniques for visibility prediction can be categorized as manual, statistical, forecasting or numerical modeling. Aviation industry depends on NiMet for its weather reports. NiMet supply the weather reports and the flight operation department plan flights base on the reports. However, the recent state of untoward accidents and incidents in some airports across the country was attributed to high unreliable weather reports which put a big question mark on the ability for the aviation authority in Nigeria to make the environment safe and conductive for flying. (Ayoade, 2004). The incidents were so bad that some Airlines, struggled to recover from the misfortunes that befall them because of wrong information given from the control tower**.** Abubakar and Nurudeen (2011) also reported cases of flight delay and cancellation due to poor visibility. They reported that flight from Kano, Abuja, Yola and other parts of the North especially were delayed for 2 hours and above due to poor visibility.

The study carried out was aim at developing forecast guidance that will aid in the forecasting of low visibility at low Murtala Muhammed Airport, Ikeja, Lagos, Nigeria by examining the weather conditions causing low visibility in Murtala Muhammed Airport, identifying the meteorological factor that favours the development of the identified conditions of low visibility, assessing the prevalent causative factor of low visibility in Murtala Muhammad Airport, predict horizontal visibility using some important weather variables identified using MLP and multiple regression and to test the effectiveness of the predictive models.

2.0 Materials and Methods

The study predominantly rely on secondary data collected over a period of ten years (2006 to 2016), they include: pressure, relative humidity, dew point temperature, wind speed, wind direction, visibility and weather events.This dataset includes reports of surface pressure, relative humidity, dew point temperature, wind speed and horizontal visibility of the study area. In order to examine the conditions causing of low visibility in the study area, records of days with low visibility (<5) highlighted, extracted alongside other variables and weather event causing it. To assess the meteorological variablesthat favours the development of the identified causative conditions of low visibility. Relationship of the weather parameters chosen in relation to low visibility occurrence will be determined. To do this, selected meteorological parameters (pressure, relative humidity, dew point temperature, wind speed, wind direction) will be correlated separately with days of low visibility caused by the identified factor using correlation analysiseach for all the weather parameters. A scatter plot will also be used to show their relationship. It is express as

$$r = \frac{\mathrm{n}(\sum \mathrm{xy}) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \qquad 1$$

Where ($\sum$ = Summation;$\sum$x = Summation of variable x (relative humidity, dew point temperature;$\sum$y = Summation of variable y (visibility);n = Number of variables;$\sum$xy = the sum of mean deviation of independent variable x and dependent variable y.)

The result was outlined in accordance to order of importance.

Two predictive models used are multiple linear regression analysis and multiple layer perceptron models. Multiple linear regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Multiple regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modelling and analysing several variables, when the focus is on the relationship between a dependent variable and more than one independent variable (or 'predictors'). This will help me understand how the typical value of visibility changes when any one of the independent variables is varied, while the other independent variables are held fixed.

A multiple linear regression model with constant predictor variables X_1, X_2…..X_x,(pressure, relative humidity, dew point temperature, wind speed, precipitation…..) and a response Y (visibility) can be written as:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_n x_n + \varepsilon \qquad 2$$

Where (Y is the dependent variable (visibility); β_0 is the Y intercept; β_1 is the change in Y for each increment change in X_1;β_2 is the change in Y for each increment change inX_2; X is the score for which I am trying to predict a value of visibility (pressure, relative humidity, dew point temperature, wind speed, precipitation))

The multi-layer perceptron (MLP) model used is mathematically as;

$$Y = \varphi\left(\sum_{i=1}^{n} wi\ xi + b\right) = \varphi\left(w^T x + b\right) \qquad 3$$

Where (w is the vector weights of inputs; x denotes the vector of inputs; b is the bias ;φ is the activation function; Y is target variable.

The predictive model was validated by comparing predicted visibility with the actual recorded visibility values. To assess the reliability of the two forecast model, the sum of square error (SSE) will be computed. SSE is the sum of the squared differences between each observation and its group's mean. It can be used as a measure of variation within a cluster. If all cases within a cluster are identical the SSE would then be equal to 0.

The formula for SSE is:

$$\sum SSE = \sum_{I=1}^{n} (X1 - Xbar)^2 \qquad 4$$

Where n is the number of observations; x_i is the value of the ith observation and Xbar is the mean of all the observations.

2.1 STUDY AREA

The study area is Murtala Muhammed International Airport, Ikeja, Lagos owned by the Federal Airport Authority of Nigeria, opened on 1979. It is the busiest and largest airport in West Africa. The airport is located in Northern Suburb of Ikeja, a Local Government Area in Lagos State. The airport has two parallel runways, one serving the international community while the other domestic flights. The airport is within the boundary of latitude 6.609N, longitude 3.334W and latitude 6.3314N, longitude 3.311W. It has an elevation of 41m(135ft). It is identified using IATA code as LOS and ICAO code as DNMM. It runs 22km (14 miles) North West of Lagos State. Using Koppens Climate classification, Lagos is under Aw, a tropical savanna climate. The region experienced both rainy season and dry season having its rainy season within April-October while its dry season by November-March. Owing to its proximity to the equator, it has a fairly moderate temperature difference with the hottest month having an average of 28.5^0 c while the coolest month is August with an average of 25.0^0c. South west trade wind influences the state most times which is responsible for its high relative humidity. (Mark et al, 2016)

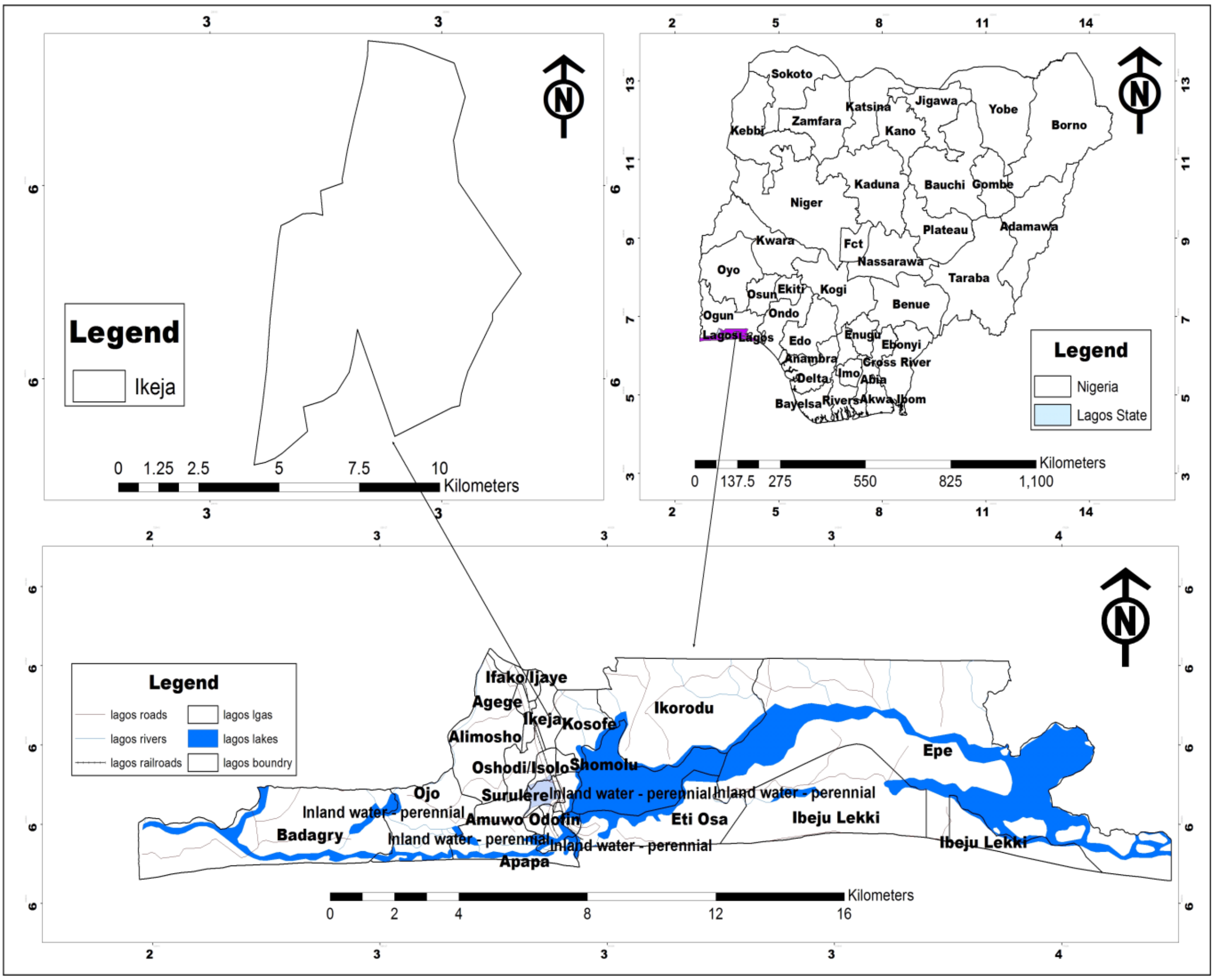

Figure 1: The study area

Source: Department of Geography FUT Minna.

2.2 DATA ANALYSIS

Conditions causing low visibility

In order to examine the meteorological conditions causing low visibility, days of recorded low visibility (< 5km) for ten years were compared with the weather conditions causing it. There are ten reported weather conditions causing low visibility at the study area. They are Fog, Mist, Rain/Thunderstorm, Partly Cloudy, Scattered Cloud, Mostly cloudy, Haze, widespread dust. There are missing conditions not reported too. It can be noted that haze mostly account as causative factor of 392 casesof low visibility followed by rain of 299 cases accounting for 23%, Mist have 250 occurrence cases with 19%, fog account for 14% with 187 cases of occurrence, partly cloudy conditions account for 7%, scattered cloud for 3%, missing reports accumulate to 3% and lastly Mostly cloudy account for 1% with 15 cases.

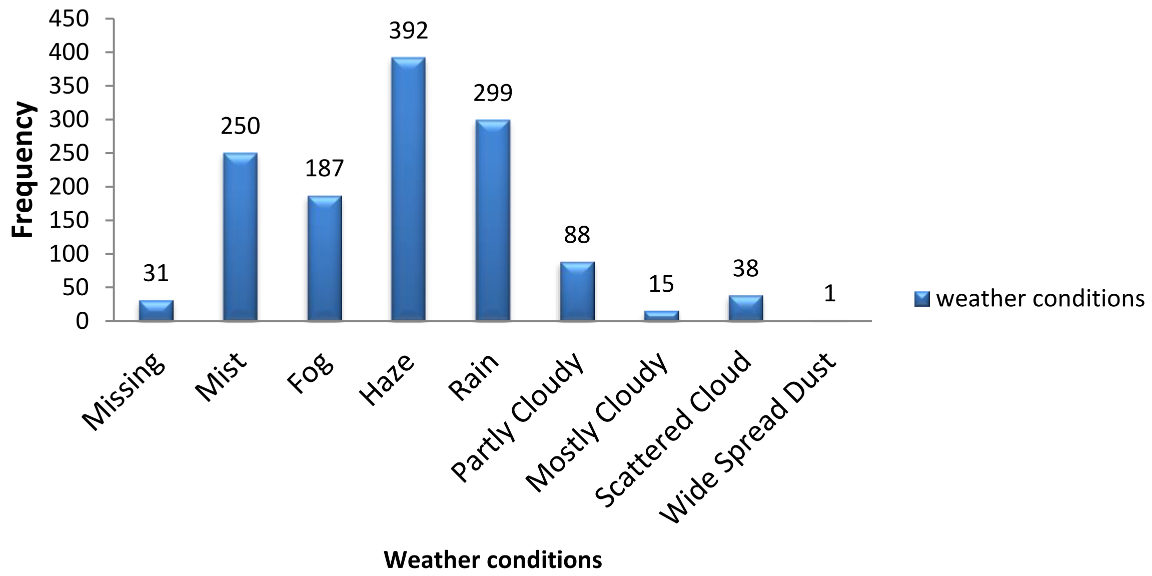

Figure 2.1 Low visibility causative conditions.

Factors that favours the development of low visibility conditions.

To determine the relationship between visibility and the chosen meteorological variables properties, Correlation analysis was used. Dew point temperature tends to have a strong positive relationship with low visibility with correlation coefficient (R^2) of 0.68. This means the lower the dew point temperature the lower the visibility in the study area. Relative Humidity (RH) has a strong negative correlation coefficient (R^2) of -0.65 which implies that the higher the relative humidity, the lower the visibility range. Other parameters shows to have a weak relationship with visibility; Pressure has (R^2) of -0.017, Wind Direction has (R^2) of 0.013 and Wind speed has R^2 of 0.018. Though wind speed and direction are of weak relationship, it indicates that when they are of low value visibility tends to be low.

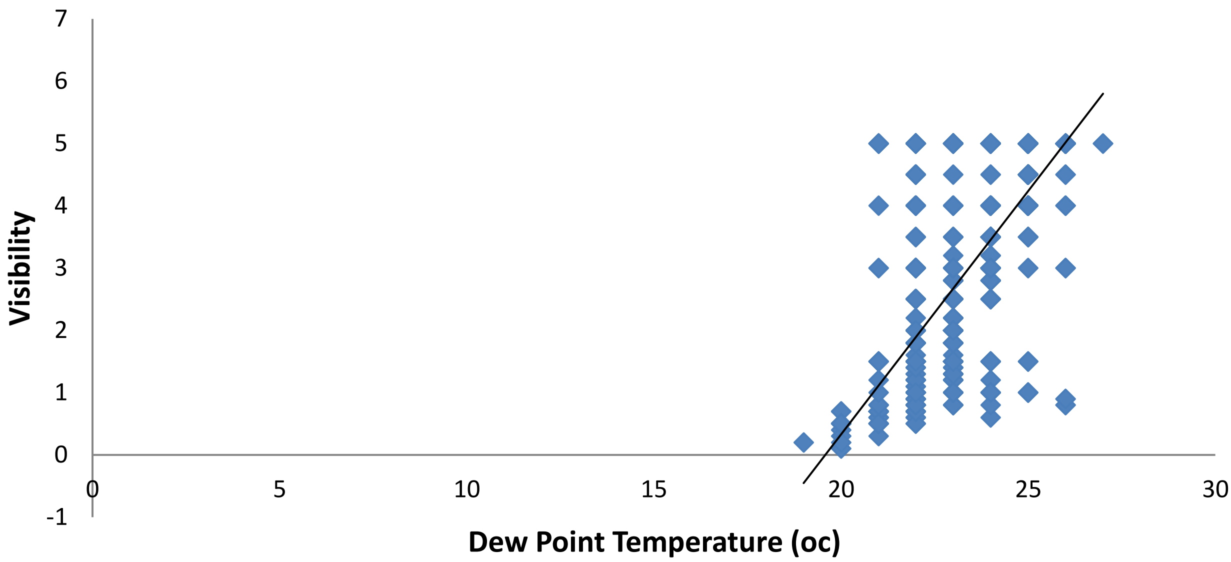

Figure.2.2 Visibility and Dew Point Relationship.

Source: Author's computation

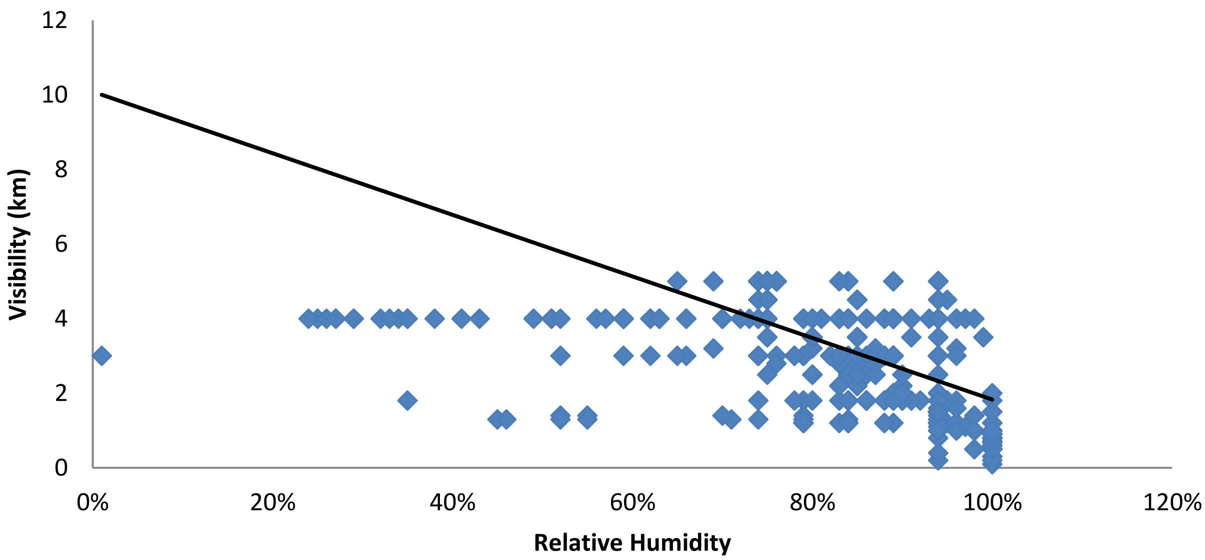

Figure. 2.3 Visibility and Relative Humidity Relationship.

Source: Author's computation

Prevalent causative factor of low visibility.

It is of paramount importance to know the prevalent causative factor of low visibility in the study area in order to build a good predictive model. Those factors of higher strength of relationship will be use as input variable. The four most important weather conditions (haze,

fog, mist and rain) that accounted for low visibility where correlated separately with dew point temperature, relative humidity, atmospheric pressure, wind speed and wind direction.
The result of correlation coefficient expressed in percentage for the four conditions are as follows:

Rain Condition: It showed for Rain conditions a relationship of 43% with relative humidity, 16% with dew point temperature, 11% with wind speed, 6% with atmospheric pressure and 4% of wind direction. This means that relative humidity is the prevalent deterministic factor of rain conditions followed by dew point temperature. These two factors shall be used for in generating the forecasting model.

Fog Condition: Theresult for fog conditions shows relative humidity to have the highest relationship strength with 78%, then dew point temperature with 31%, wind direction with 14%, wind speed and pressure account for 7% each. From the analysis it can be observed that Relative humidity is a deterministic factor of fog conditions followed by dew point temperature as opposed rain condition. They will be used in developing the forecasting model.

Mist Condition: Result of correlation analysis of causative factors for period of low visibility reported to be caused by mist account to have dew point temperature relationship of 66% and 22% of relative humidity. Wind speed account for 15%. Pressure and wind direction have the same importance of 6%. From the analysis it can be observed that dew point is the deterministic factor of fog conditions followed by relative humidity. These two variables will be used in developing the forecasting model.

Haze condition: Low visibility caused by haze have a relationship with dew point temperature with a percentage of 55% followed by relative humidity of 40%, wind speed and direction have almost the same percentage 8% and 9% respectively.

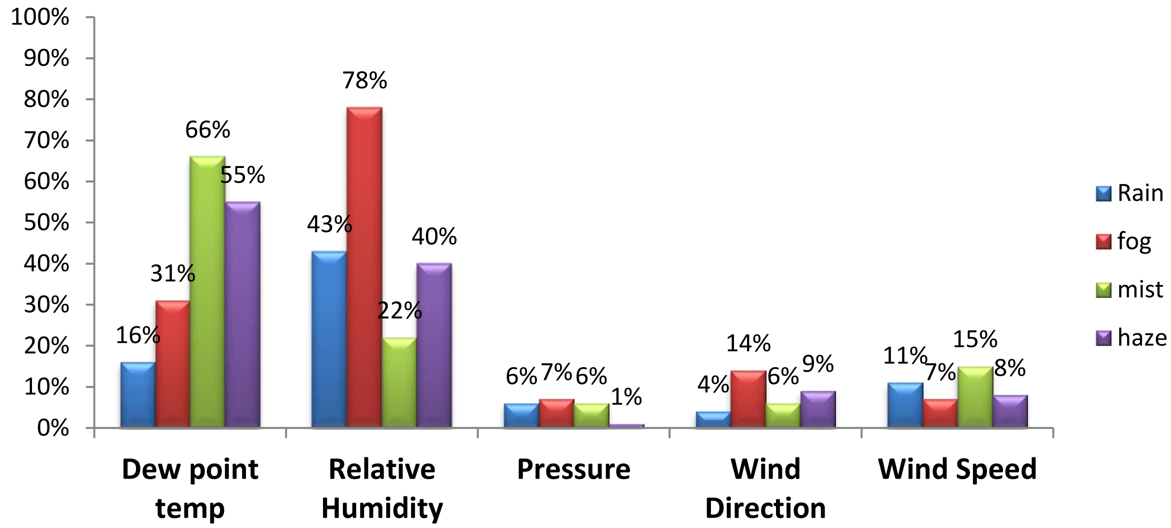

Figure 2.4 Relative percentage of causative factors and weather condition.

3.0 Results

Multiple regression analysis was carried out using two input variables with the highest relationship with visibility. The following are the model result for various conditions causing low visibility in the study area:

Rain Condition: After the analysis on the low visibility caused by rain using the two prevalent causative factors (relative humidity and dew point temperature, the developed model equation is

$$\text{Visibility} = 5.534 - 4.236RH + 0.087D_wT \quad 3.1$$

Where RH is Relative Humidity and D_wt is Dew Point Temperature.

Fog: Result of analysis for low visibility caused by fog using the two prevalent causative factors (relative humidity and dew point temperature), the developed model equation is

$$\text{Visibility} = 10.31-11.722RH + 0.098D_wT \quad 3.2$$

Where RH is Relative Humidity and D_wT is Dew Point Temperature.

Mist Condition: After carrying out my analysis for low visibility caused by mist using the two prevalent causative factors (relative humidity and dew point temperature), the model equation isVisibility $=-11.375-1.009RH + 0.620D_wT$

4.3

Where RH is Relative Humidity and D_wT is Dew Point Temperature.

Haze: After carrying out my analysis for low visibility caused by haze using the two prevalent causative factors (relative humidity and dew point temperature), the model equation is

Visibility = -5.995-1.852RH + 0.466DwT 3.4

Where RH is Relative Humidity and D_wT is Dew Point Temperature.

Multilayer Perceptron Model Result

Rain Condition: In order to train the MLP model, 391 cases of low visibility due to rain conditions were used of which 294 was valid while 97 invalid. 207 cases which is 70.4% of the data was for training while 87 cases which is 29.6% used in testing it. For the input layers two factors used are relative humidity and dew point temperature with 30 numbers of units. 1 number of hidden layer was used in training with 4 units using hyperbolic tangent as activation function. The output layer containing the dependent variable (visibility) has 12 numbers of units using identity as activation function. To calculate the error in modelling, error function used was sum of square. Sum of Square error of the training data set gave 37.086accounting for 23.7% incorrect predictions while sum of square error for the testing data set gave 15.470 accounting for 23.0% incorrect predictions.

Haze Condition: In order to train the MLP model, 391 cases of low visibility due to haze conditions were used. 73.4% (281 cases) of the data was for training while 26.6% (102 cases) were used in testing it. For the input layers two factors used are relative humidity and dew point temperature with 40 numbers of units. 1 number of hidden layer was used in training with 4 units using hyperbolic tangent as activation function. The output layer containing the dependent variable (visibility) has 13 numbers of units using identity as activation function. To calculate the error in modelling, error function used was sum of square. Sum of Square error for the training data set gave 42.986accounting for 21.0% incorrect predictions while sum of square error for the testing data set gave 13.97 accounting for 17.6% incorrect predictions.

Fog Condition: For the MLP model, 391 cases of low visibility due to fog conditions were used. 66.5% (121 cases) of the data was for training while 33.5% (61 cases) used in testing it. For the input layers two factors used are relative humidity and dew point temperature with 11 numbers of units. 1 number of hidden layer was used in training with 4 units using hyperbolic tangent as activation function. The output layer containing the dependent variable (visibility) has 12 numbers of units using identity as activation function. To calculate the error in modelling, error function used was sum of square. Sum of Square error for the training data set gave 30.877 accounting for 39.7% incorrect predictions while sum of square error for the testing data set gave 15.953 accounting for 39.3% incorrect predictions.

Mist Condition: For the MLP model, 391 cases of low visibility due to mist conditions were used. 69.8% (171 cases) of the data was for training while 30.2% (74 cases) used in testing it. For the input layers two factors used are relative humidity and dew point temperature with 31 numbers of units. 1 number of hidden layer was used in training with 3 units using hyperbolic tangent as activation function. The output layer containing the dependent variable (visibility) has 16 numbers of units using identity as activation function. To calculate the error in modelling, error function used was sum of square. Sum of Square error for the training data set gave 42.823accounting for 36.3% incorrect predictions while sum of square error for the testing data set gave 20.116 accounting for 39.2% incorrect predictions.

Model Validation

It is important to test the effectiveness of the developed model. To do this mean means square error was computed and the following are the result of the analysis: It shows the level of variation within the prediction output. Prediction of low visibility (caused by rain condition) using multiple linear regression have a SSE of 9.1 while Multilayer perceptron have a SSE of 15.5. Hence model from multiple linear regressions is better use in predicting low visibility during rainy conditions. Multilayer Perceptron on the other hand is better use in predicting low visibility during haze, fog and mist conditions as it has a lower SSE. The table below gives the sum of square error result for both predictive models:

Table 2.1 Result of Sum of Square error

Conditions	MLP Sum of Score Error	Multiple linear regression Sum of Score Error
Rain	15.470	9.71897685
Haze	13.97	130.0599
Fog	15.953	45.10369
Mist	20.116	28.67589

Source: Author's computation

4.1 **Conclusion**

Weather forecasting is of paramount importance in aviation operation at MurtalaMuhammed International Airport. This research is aim at generating a technique that will aid in predicting low visibility at the airport. The result of my analysis indicates that it can be ascertain that four major weather conditions account for the cause of low visibility. They are haze, rain, fog and mist. Development of these weather conditions are favoured by two major causative factors which are Relative Humidity and Dew Point Temperature, following the result of correlation analysis. Relative humidity, dew point temperature are important input variables for developing low visibility predictive model as they show greater relationship compare to wind speed, pressure and wind direction.. Days of high RH tends to bring about low visibility while reduction in dew point temperature favour low visibility occurrence. Hence, it is reasonable to conclude on the effectiveness of using these two causative factors in developing predictive model for low visibility. Multilayer Perceptron (MLP) and multiple linear regression analysis are the two predictive model used and it shows that MLP generated a model which is good for predicting low visibility for haze, fog and mist conditions while Multiple Linear Regression model is good for predicting low visibility during low visibility on rainy conditions. In conclusion the use of MLP in developing forecasting model should be look into by weather experts.

4.2 Recommendations

Weather affects aviation operations and could be improved upon by monitoring and understanding the relationship of weather variables. Accurate weather observation is very important for it is the back-bone of weather forecasting as present weather records serves as input variables upon which forecast models are built, hence accurate reports should be made.

In order to get accurate forecast of low visibility in the study area it is of paramount important to also consider values of dew point temperature, relative humidity, rain and mist as they are the main causative factors of low visibility in the airport. The use of models such as multilayer perceptron which uses artificial intelligence to learn and recognise pattern should be employ in weather forecasting. Although from the result it showed that it behaves poorly during rainy conditions compare to regression model, therefore forecasters should not rely on just one model but should employ the use of different models in forecasting.

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