INVESTIGATATION OF HAZARDOUS WEATHER AND ITS IMPACT IN AVIATION OPERATION IN KENYA CASES STUDY JOMO KENYATTA INTERNATIONAL AIRPORT

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I10/1690/2020

A research project submitted in partial fulfillment award of the undergraduate degree in Bachelor of Science in meteorology.

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DECLARATION

I declare this project to be my original work and out of my research and its original content. Where my own work has been used, this has been properly acknowledged and referred in accordance with the University of Nairobi's requirements.

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ACKNOWLEDGEMENT

I thank God for the far he has brought me. I give special thanks to everyone who has been with me throughout my study session. I thank my family for being part of this giving me support .I would also want to thank my lecturers, Dr Bethwel Kipkoech and Dr Jane Mugo for their support and guidance

I would also wish to acknowledge my friends who assisted me when there was need.

DEDICATION

I dedicate this project to my parents Joseph Owuoth and Pamela Akeyo who has always show consistency on getting knowledge on how flight manages hazardous weather conditions.

ACRONYMS ABBREVIATIONS

KMD –Kenya Meteorological Department

WMO –Word Meteorological Organization

JKIA - Jomo Kenyatta International Airport

QNH -Question Nil Height (measurement; pressure at sea-level; aviation)

QFE -Atmospheric pressure (Q) at Field Elevation (aviation)

A**IRMET** –Airmen's Meteorological Information

KCAA –Kenya Civil Aviation Authority

IATA -International Air Transport Association

ICAO -International Civil Aviation Organization

AMSL -Above Mean Sea Level

GDP-Gross Domestic Products

IPCC -Intergovernmental Panel on Climate Change

USA -United States of America

IFR -Instrument Flight rules

VFR -Visual Flight Rules

MAM -March-April-May

DJF -December-January-February

JJA -June-July-August

SON -September-October-November

NTSB-The National Transportation Safety Board

VFR-Visual Flight Rule

IFR-Instrument Flight Rule

GDP-Gross Domestic Product

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ABSTRACT

This project work focuses on hazardous aircraft weather forecasts in Kenya. The weather parameters analyzed include fog, temperature and rain.

The main objectives of this field of study is to assess the impact of fog, temperature and rain on aviation operation in Jomo Kenyatta Airport. This was achieved by determining the temporal variation of both minimum and maximum temperature and also determining the relationship between minimum temperature and fog days.

Data used in this project include temperature measured in degrees Celsius, rainfall measured in millimeter and fog used was classified according to days of occurrences. Pearson correlation coefficient was computed to show the linear relationship minimum temperature and foggy days and the correlation was weak.

Missing values were estimated using single mass curve and the use arithmetic mean method. Time analysis was used in determination of temperature, rain and fog occurrence.

In the results, there was a general increase trend in maximum and minimum temperatures. They also showed an increase in the number of foggy days in the MAM and SON seasons. There was also a relationship between minimum temperature and fog days. A simple linear regress therefore was established. Coldest temperature in DJF for minimum temperature. February has the maximum temperature for maximum temperature.

Various techniques were used to determine the accuracy in this project. For visibility and temperature are given at the forecast office at every 6 hours improving the efficiency. For visibility fog occurrence was used per month for the period of 2009 to 2018 through the use of graphs and correlation method

Rainfall as its ability of its showers turbulent air determined here as it cause sudden and unpredictable changes in aircraft altitude speed and direction. Rainfall causes flood in the airport and in the runway for instant, this making landing and taking off difficult. For rainfall experienced in JKIA was used from 2009 to 2018

CHAPTER ONE

1.1 INTRODUCTION

In aviation, hazardous weather refers to any naturally occurring weather condition that has the potential to cause either harm or damage in aviation industry.

Hazardous weather conditions brings a substantial threat to aviation safety, as they can lead to accidents, numerous challenges for pilots and air traffic controllers. Pilots depends deeply on weather forecasts to plan for safe flight operations, making accurate and timely weather information critical for the aviation industry. Bad weather events such as rain accompanied by thunderstorms, high temperature, and low visibility can all have serious implications for flight operations, needing the need for thorough forecasting and proper decision making.

Weather forecasting tools and technologies have advanced significantly in recent years, allowing for better predictions of hazardous weather conditions. These advancements have enabled aviation professionals to better plan for and respond to adverse weather events, reducing the likelihood of accidents and incidents caused by weather-related factors however this has not solved all issues.

The forecasts form part of the Terminal Aerodrome Forecast (TAF) provided by aerodrome meteorological office.TAF comprises of forecast for wind speed and direction, visibility, weather and ceiling conditions

Temperature Pressure relation plays a significant role in the aviation industry, affecting various aspects of operation and safety. As aircraft climb to higher altitudes, the pressure decreases as temperature increases, pressure which can have a significant impact on aircraft performance, particularly in terms of engine efficiency, aerodynamics, and passenger comfort.

Verification of the forecast depends entirely on the quality of the observable data. The contention for concern apart from the quality of data is the treatment of change groups in the forecast and scores allocation at each time. The TAF employs the use of BECMG within a time period, FM for beginning at a specified time, TEMPO for temporary changes and PROB for changes expected probability of mostly 30% or 40% is employed in the TAF.

Example of a meter outlook in JKIA METAR: HKJK 290730Z 02006KT 330V070 9999 BKN022 BKN090 23/17 Q1022 NOSIG.

The trend forecast involved of a concise statement of the expected significant changes in the meteorological conditions at that aerodrome to be appended to a local routine report, local special report, METAR or SPECI. The validness of a trend forecast shall be 2 hours from the time of the report which forms part of the landing forecast. The information is valid for pilots for landing and taking off of flights

1.2 JUSTIFICATION

Weather hazards are meteorological phenomenon that poses a great operational challenge to aircrafts. A little research has been done on forecasting despite serious related aviation problems.

Jomo Kenyatta International Airport is a fast-growing transport system between Nairobi, other regions. The aerodrome operations are affected by fog, temperature and rain which either leads to delays, accidents, cancellations or diversions of her flights.

The research would also contribute towards safety and efficiency in operation and generally the smooth running of aerodrome activities.

1.3 OBJECTIVES OF THE STUDY

The main objectives of this field of study is to assess the impact of fog, temperature and rain on aviation operation in Jomo Kenyatta Airport.

1.3.1 Specific objective of the study

(a)To find out the relationship between flight delays cancellation and divergences due to weather.

(b) To determine the variations of fog, temperature and rain at JKIA.

1.3.2 Scope of the study

This study aims at quantifying the effects of fog temperature and rain on commercial aviation, a case study in Jomo Kenyatta International Airport in Kenya Planning for events will help aviation industry to reduce the vulnerability of the pressure.

1.4 AREA OF THE STUDY

The study area in this case is Jomo Kenyatta International Airport. Located in the Embakasi suburb 18 kilometers (11 mi) southeast of Nairobi's central business district. The City of Nairobi is located at longitude 36 50' E mid 1 18' S. The mean altitude is around 1,700 meters above the mean sea level but as the city has a highly variable topography, this height ranges from l, 600m (to the East) to over 1,800 (to the West and Northwest of the Central Business District (CBD).

Location Nairobi, Kenya latitude: 01-19S, longitude: 036-55E,

Elevation: 1624 m

Runway 4,117m/13,507ft

Direction: 06/24

Statistic (2023)

Economic Impact

5.1% of GDP (totaling to $0.8 billion in Kenya)

Figure1: Map of Nairobi showing location of JKIA image from google 2024

CHAPTER TWO

2.0 LITERATURURE REVIEW

Hazardous weather conditions lead to high risks in aviation industry and safety, with overwhelming impacts for passengers and the crews in the flight too. For risks to be diminished pilots and flight operators depends largely on updated weather conditions and information making them good in decision-making in-flight operations. This literature review will focus on three main weather factors affecting aviation. The phenomena are rain, fog and temperatures the reviews deal with the phenomena as follows:

Figure 2 fog image from google 2024

2.1 FOG

Fog is often defined as simply a cloud a cloud of tiny water droplets suspended in the atmosphere at or near the earth's surface that limits visibility as a result of cooling or humidification process.

2.1.1 Types of fog

There are two types of fog formation processes: cooling the surface by radiation of heat and by advection of moist air over an already cool surface. In both cases air above the surface will cool to it dew point but the way it does that is different as are the circumstances surrounding it.

2.1.2 Advection Fog

This type forms when moist air moves over an already cold surface and cools from below so that the temperature reaches its dew point the air gets saturated and condensation will take place. There already is a wind moving this air so we have a mixing process taking place at the same time

2.1.3 Frontal Fog

On the approach of a warm front, where the warm air will move Overhead the heavier cold air with light winds and any precipitation into the cold sector ahead of the warm front the cool air will cause saturation and fog / stratus development.

Upslope is the same as frontal fog, warm and moist air moving over a cool layer (be that an mountain or hill upslope or a cool pocket of air), it's just a different name for the same phenomena.

2.1.4 Radiation Fog

Radiation tog forms overnight as the air near the ground cools and stabilizes. When this occurs the air to reach saturation, fog will form. Fog will first form at or near the surface, thickening and continues to cool. The layer of fog will also deepen overnight as the air above the initial fog layer also cools. As this air cools, the fog will extend upward, the most favored areas for fog development ae

Sheltered valleys where there is little to no wind and locations near bodies of water. Wind would disrupt he formation of radiation fog Radiation fog is usually patchy, tends to stay in one place and goes away the next day under the sun's rays. Thicker instances of radiation fog tend to form in valleys or over water bodies.

When fog occurs over airfield runways, pilots and air traffic control personnel are at risk of aircraft operations. The Tenerife airport disaster occurred on March 27, 1977, when two Boeing 747 passenger jets collided on the runway at Los Rodeos Airport.

The prevailing visibility is reported in statute miles it is reported in both miles and fractions of miles. At times, runway visual range (RVR) is reported following the prevailing visibility. RVR is the distance a pilot can see down the runway in a moving aircraft. When RVR is reported, it is shown with an R, then the runway number followed by a slant, then the visual range in feet. For example, when the RVR is reported as R17L/140OFT, it translates to a visual range of 1,400 feet on runway 17 left.

Airport operation Fog affects very heavily airport operation (Allan et al., 2001). It is one of the weather events provoking more flight delays and cancellations (Robinson, 1989). Many airports are located in areas where fog can take place, in the flat t bottoms of basins or near the coast. Typically 1% of the time fog may affect an airport.

Visibility was categorized into three of poor covering range between 0-1000m, fair between 2000-4000m and clear between 5000-9999.

2.2 RAIN

Rain a liquid precipitation formed by saturated clouds. Largely reduces visibility.

Flooding caused by rain can have a significant impact on aviation operations, mostly at airports located in low-lying areas or near bodies of water. When runways and taxiways are flooded, aircrafts are unable to take off or land, leading to flight delays and cancellations. Rainfall largely affects in aviation in terms of flooding and leaks For VFR pilots that might mean that flight visibilities fall below the legal minimum. If that happens, they'll have to divert course and land to keep from breaking the rules.

Flooding damages airport infrastructure, such as terminals, hangars, and navigation equipment. In JKIA there have been several reports that the infrastructure have been damaged leading to leakage this making it less effective Repairing and restoring these facilities can be costly and time-consuming, further disrupting aviation activities. Floodwaters can affect the safety of aircraft operations by causing erosion of runways and taxiways or compromising the structural integrity of buildings. This poses a risk to both flight crews and passengers, necessitating thorough inspection and maintenance to ensure the safety of all operations.

In 1997 for instance there were two accidents, involving the loss of large transport aircraft, which occurred in very heavy rain. The first casualty was a Korean Airlines Boeing 747 which came down on Guam, and the second, a Vietnamese Tupolev in Cambodia. Both aircraft accidents occurred in torrential rain on approach to an airport.

Thunderstorm and lighting Thunderstorms can produce severe turbulence, dangerous winds, hail, and heavy precipitation, all of which can impact aircraft performance and pose a safety risk. Lightning strikes are a particularly concerning aspect of thunderstorms, as they can cause damage to aircraft systems and even lead to catastrophic accidents.

AT JKTA, about 69.47% of flight delays are caused by rainfall and also, about 7626% of flight diversions are caused by rainfall. These flight incidence occurrences follow a temporal pattern as rainfall. The highest frequency of occurrence for delays is one incident per month while that of diversions is three incidences per month. Therefore. Rainfall contributes to air traffic delays diversions. (Otieno 2016)

2.3 TEMPERATURE

This the measure of average kinetic energy (KE) of a gas, liquid, or solid.

There have been constant increase in temperature since 1850 at an approximate of +90.9K.Global warming due to human activities poses climate change resulting to an increase in temperature this best estimate 2.8^{o}C . This increases possible risks that includes worsening of aircraft performance of the engine, reduction of payload and changing flight rout vertically. The changes will largely affects aircraft performance resulting to weight restriction to weight restriction especially airports with short runways (E.Coffel et.al.2014)

In case of excess weight these are some outcomes: Higher takeoff speed

Longer takeoff run

Reduced rate and angle of climb

Lower maximum altitude

Shorter range

Reduced cruising speed

Reduced maneuverability

Higher stalling speed

Higher approach and landing speed

Temperature increases, air density decreases. This affects aircraft performance parameters such as lift, drag, and thrust. In warmer temperatures, the air is less dense, leading to reduced lift generation, which can affect takeoff performance and climb rates.

Hot temperatures can affect fuel efficiency due to changes in engine performance and aerodynamic factors. Aircraft may consume more fuel during takeoff and climb phases in warmer conditions, impacting operational costs and range

Observed weather conditions are used in flight preflight planning stage. The printed to be familiar with are the terminal aerodrome forecast (TAF), aviation area forecast (FA), inflight weather advisories (SIGMET, AIRMET), and the winds and temperatures aloft forecast (FB). Terminal Aerodrome Forecasts (TAF) A TAF is a report established for the five statute mile radius around an airport. TAF reports are usually given for larger airports. Each TAF is valid for a 24 or 30-hour time period and is updated four times a day at 0000Z, 0600Z, 1200Z, and 1800Z. The TAF utilizes the same descriptors and abbreviations as used in the METAR report. The TAF

CHAPTER THREE

3.0 DATA AND METHODOLOGY

Data and methods used to achieve the objective of the project is presented in this chapter.

3.1 Data

3.1.2 Data sources

The data was extracted from aviation routine weather reports (METAR) database available in Kenya Meteorological Department Data Archive and JKIA.

The METAR data are reported hourly at the station. The data used for this station was extracted from 2009 to 2018

Number of flight incidences: Daily number of flights affected.

The data that was used in this study include, temperature measured in Fahrenheit or degrees Celsius, rainfall and fog number of occurrences per day

3.1.1Data quality control

Missing data and errors due to observation and due recording may occur therefore for accuracy data quality control was done through the following

(a)**Homogeneity test.**

There was need to check for homogeneity of the data after estimating the missing data. This was done using single mass curve analysis method. A graph of cumulative frequency of the data against time was plotted

(b) **Arithmetic mean method.**

This method was done to fill missing data in temperature

$$X=1/2 \sum_{i=1}^{n} xi$$

Where:

X= missing data to be estimated.

n= total number of data points.

Xi= available data points

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3.2 METHODOLOGY

3.2.1 Determination of variation of fog and temperature

Time series method

A time series is a collection of data sets which are measured at equal time intervals therefore it is a function of time and also to determine flight cancellation.

This method was used to determine the temporal variation in maximum and minimum temperature and fog incidences at JKIA. Graphs of average monthly maximum and minimum temperatures against time for the period 2009-2018 were plotted to show the temporal variation of both parameters. A graph of the monthly average number of foggy days against time in months for the period 2009-2018 was plotted to show the temporal variation of fog.

3.2.3. Correlation Method

This method was used to show if the average monthly minimum temperature and average number of fog days were relate.

$$r = n(\sum xy) - (\sum x)(\sum y) / \sqrt{\{n \sum x^2 - (\sum x)^2)(n \sum y^2 - (\sum y)^2\}}$$

Where:

r is the correlation coefficient.

x is the minimum temperature (Independent variable)

y the number of fog days (Dependent variable)

n is the number of data points

if r=0 no significant relationship between foggy days and minimum temperature

r≠0 the is significant relationship between foggy days and minimum temperature

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION FROM VARIOUS ANALYSIS

Results obtained are discussed in this chapter.

4.1 FOG

4.1 Results of fog total occurrence per year.

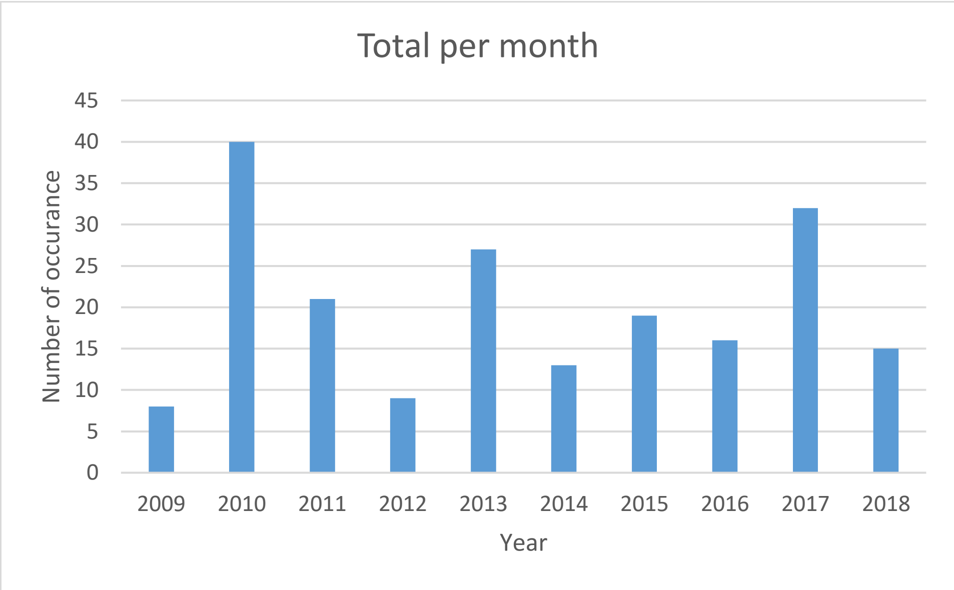

Figure 3: fog total occurrence per year

Bars on the graph shows the variation in fog events throughout the year. Higher peaks during times when conditions are most favorable for fog formation. The year 2010 having the more number of occurrences, 2009 having the least since the fog formation condition were not favorable.

Homogeneity test for fog occurrence per year

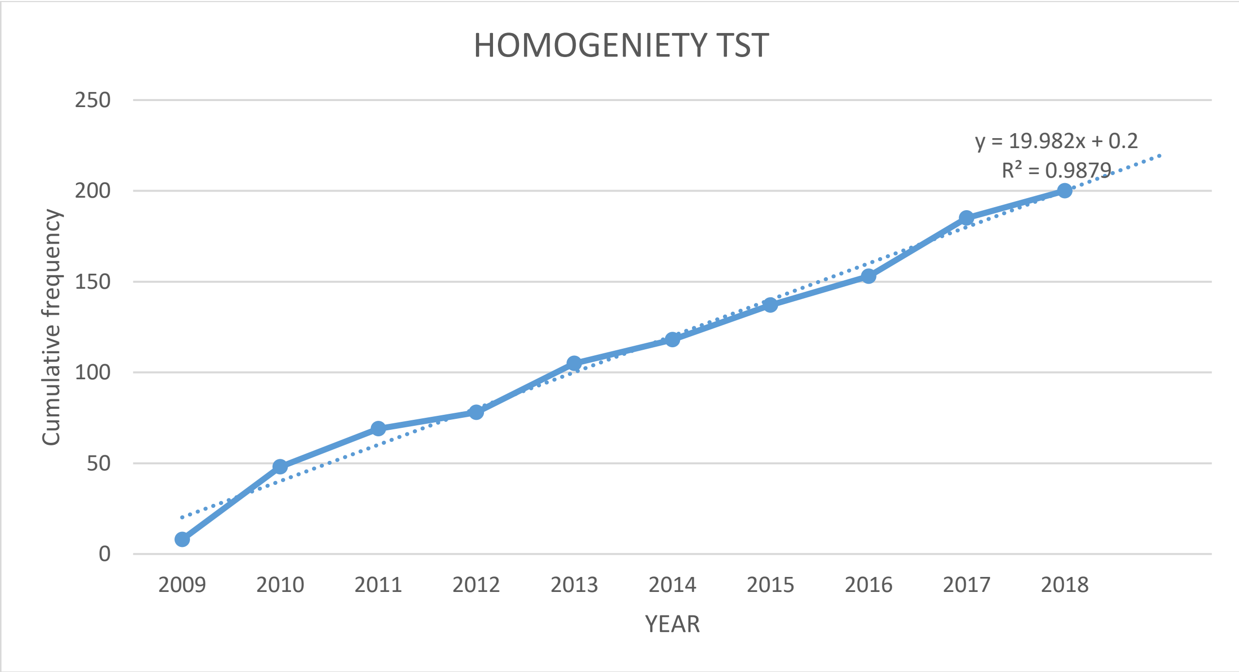

Figure 4: cumulative frequency graph against the year of occurrence.

There was need to test for homogeneity in the data analysis in relation to data comparison.

Results of fog total occurrence per month.

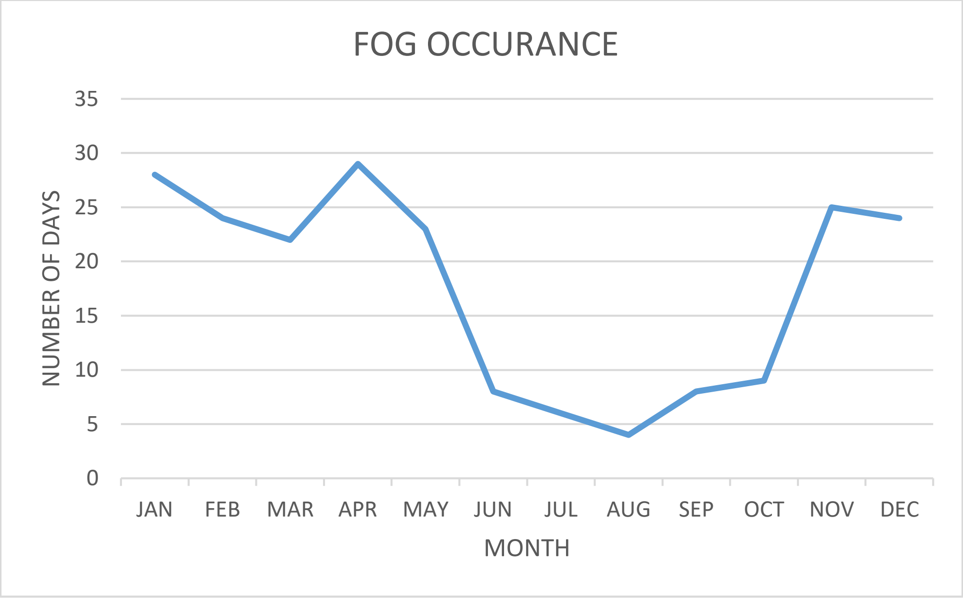

Figure 3: Monthly fog occurrence

Figure 4: Number of days graph against the month of the years allocated

The bar graph above entails the peak period of the month of fog occurrence, the trend shows an increase in between March April, April having the highest days in the occurrence and August having the least for the given years (2009-20018).

An increase in September October November (SON) and decrease in June, July, August (JJA) and decrease in December January February (DJF)

RESULTS OF CORRELATION BETWEEN FOG DAYS AND MINIMUM TEMPERATURE

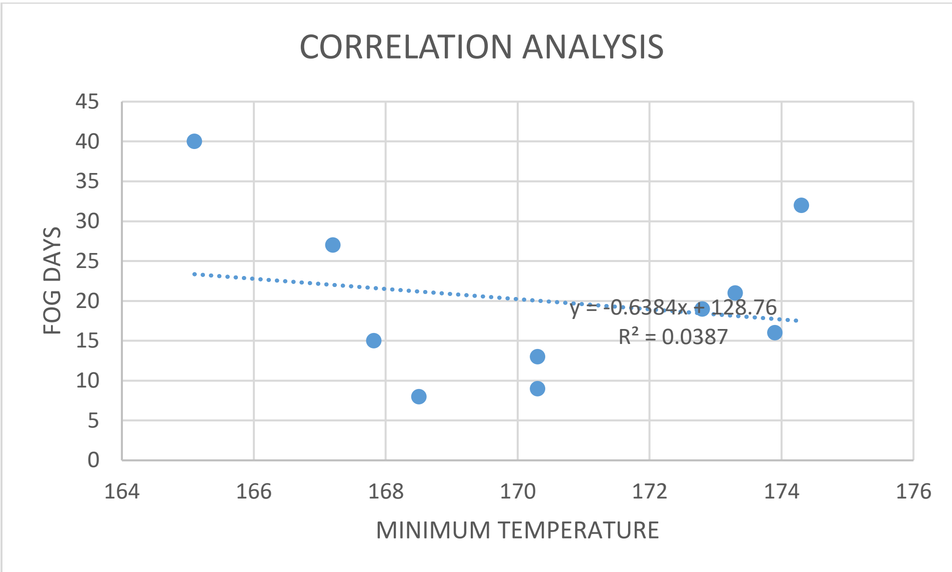

Figure 5: correlation analysis

Correlation coefficient = -0.19674

This implies that the a negative correlation between the two variables and confirms the result reached by visual examination of scatter plots and has tendency to go in opposite direction and this give that there are some aspects leading to foggy conditions.

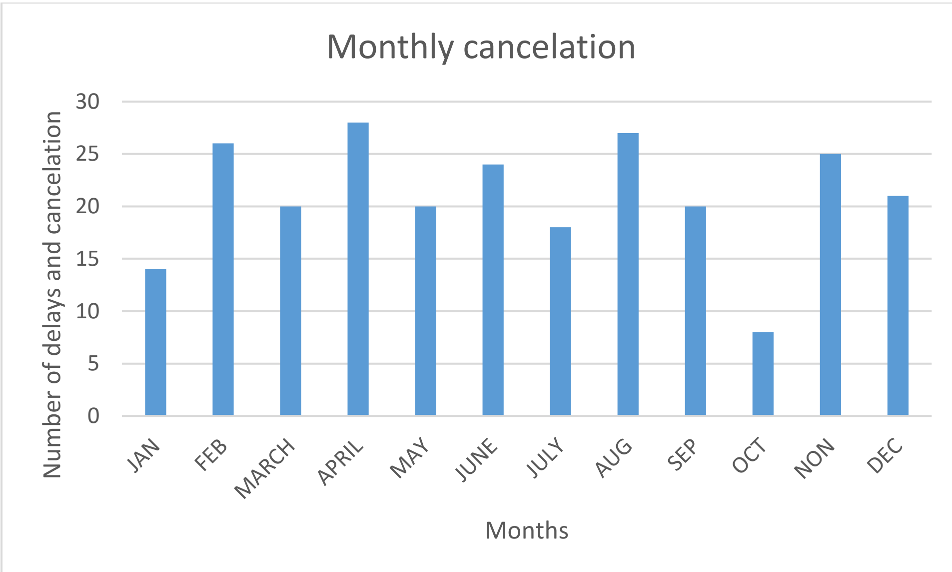

Figure: 6 Flight cancelation due to weather

The graph above gives monthly weather cancelation of flight for the period of 2009 to 20018. October having the lowest, April having the highest

Table 1 t-Test: Paired Two Sample for Means for minimum temperature and foggy days

	Variable 1	*Variable 2*
Mean	22	19.83333
Variance	25.6	44.56667
Observations	6	6
Pearson Correlation	-0.21316	
Hypothesized Mean Difference	0	
df	5	
t Stat	0.577123	
P(T<=t) one-tail	0.294433	
t Critical one-tail	2.015048	
P(T<=t) two-tail	0.588867	
t Critical two-tail	2.570582	

From the above temperature and foggy day's occurrences, the mean value increases significantly, Pearson correlation of -0.21316 indicting weak negative correlation between the two variables. This means when temperature decreases the foggy conditions increases.

For the t-stat we do not reject the hypothesis since it is significant and it's above typical significant level of 0.05.

4.2 TEMPERATURE

<u>TEMPORAL TEMPERATURE VARIATIONS</u>

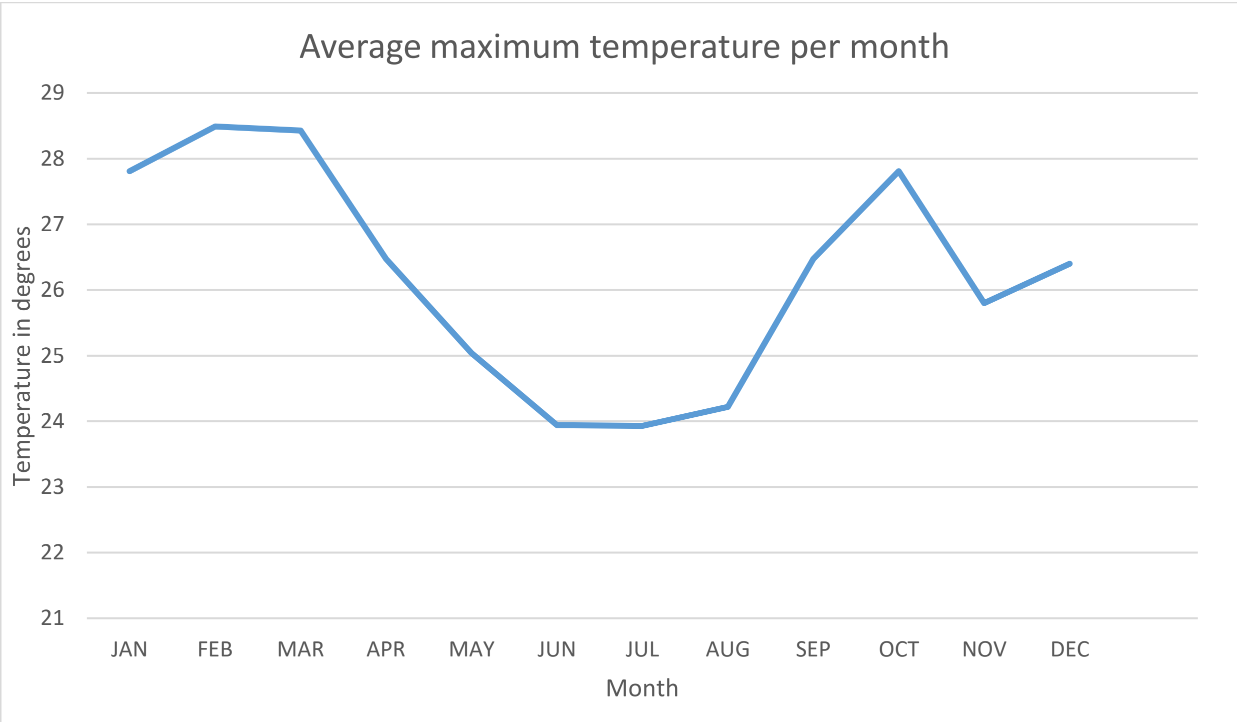

Figure 7: Average temperature variation per month

From the graph above, there was an increase in temperature in the months of December January to February (DJF) with the highest occurring in February at about 28.4$^{\ddot{O}}$C. The temperature then began to drop between March April and May (MAM) at about 23.9 ^{O}C. From there, it began to rise to around June July August (JJA) a sharp rise at September October then a decrease in temperature.

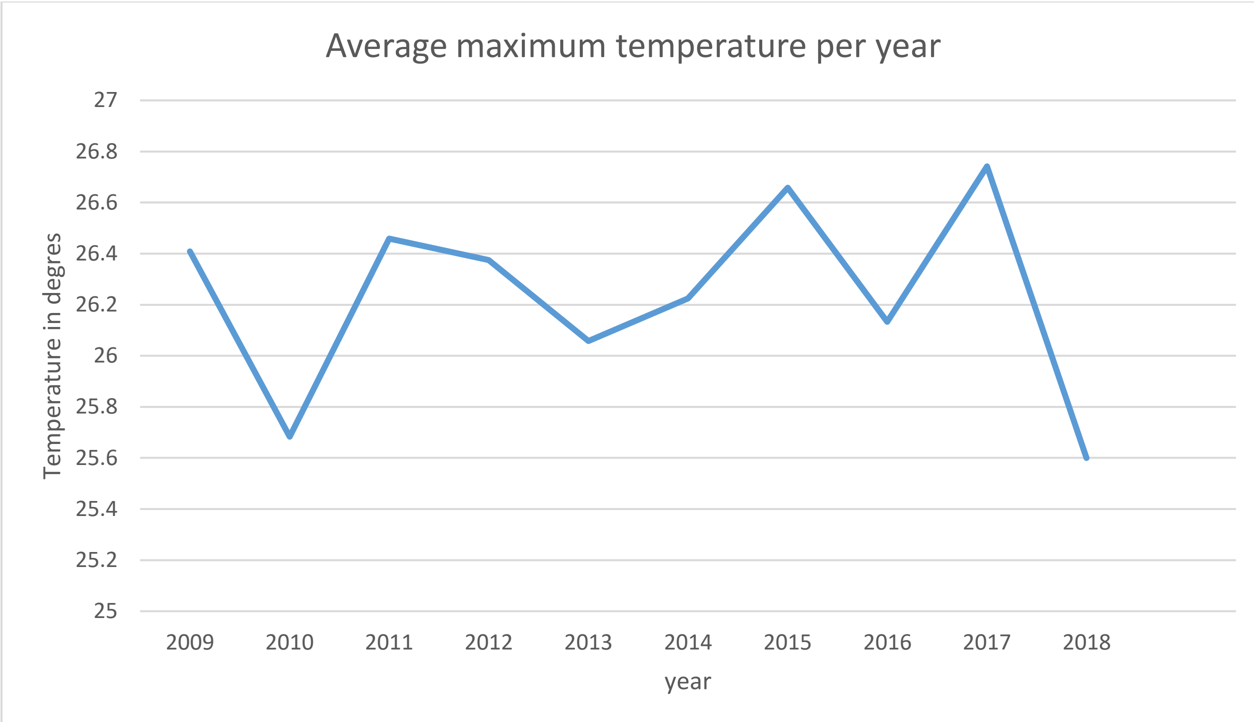

Figure 8. Average temperature variation per year

The above graph above shows the temperature variation within the given year from 2009 to 2018.

From the graph the trend gives a decrease in 2018 that is the lowest and maximum in 2017.

4.2.1 MINIMUM TEMPERATURE

Average minimum temperature per month.

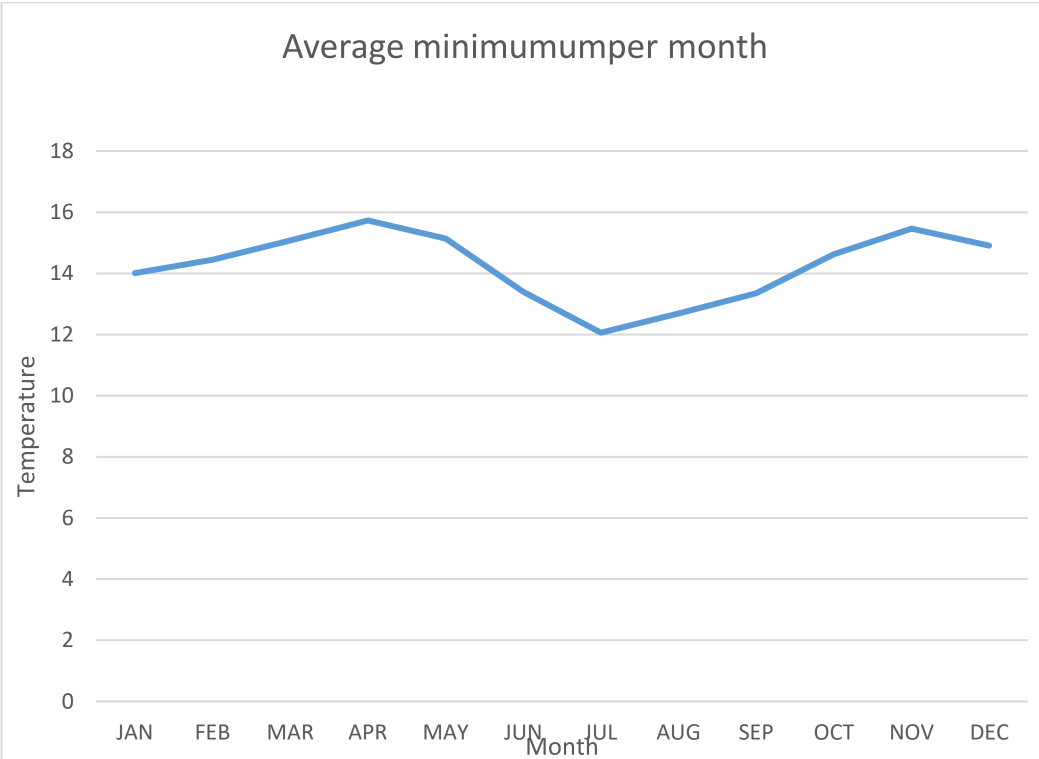

Figure 9. Average minimum temperature per month.

According to the graph, the coldest month is December, January and February (DJF). The warmest month is July and August, with the coldest on the month in July. The period of March April May (MAM), showing a decrease of temperature. The increase in temperature in the month of September October November (SON).

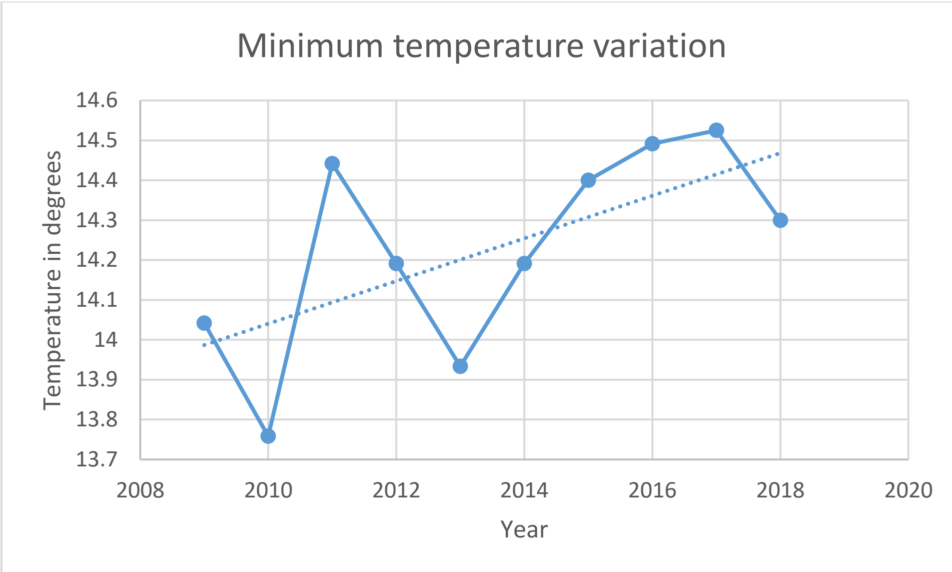

Figure 10. Average minimum temperature per year.

The above graph above shows the temperature variation within the given year from 2009 to 2018.

From the graph the trend gives a decrease in 2010 that is the lowest and maximum in 2017.

Homogeneity test for minimum temperature

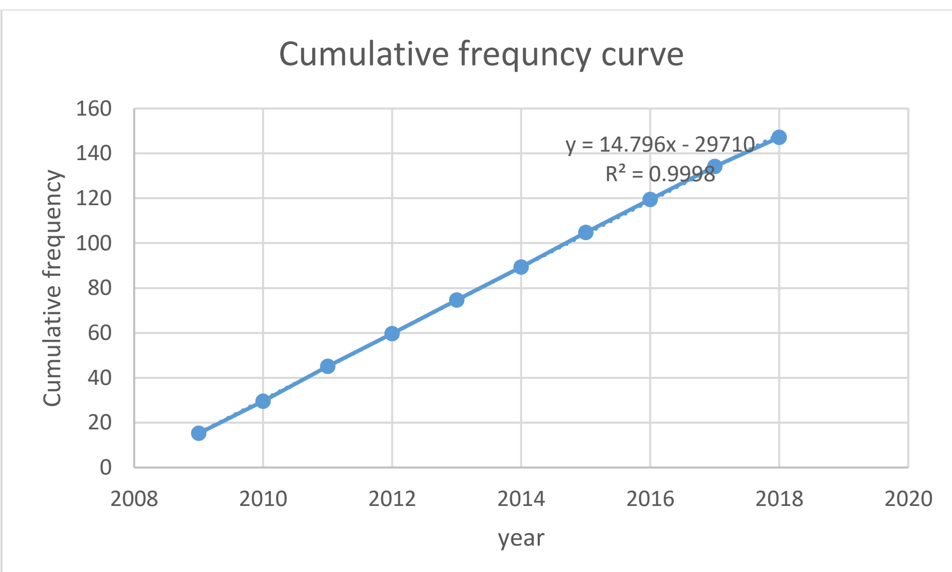

Table 2 T test for minimum temperature.

MEAN 1	MEAN 2	T START	T1	T2	REMARKS
86.16667	163.8333	-9.02992	2.015048	2.570582	Increasing significantly

T test for minimum temperature

4.3 RAINFALL

Figure 11. Rainfall average per year in JKIA

According to the graph, the year with the most rainfall was 2015. The year with the least rainfall was 2017 in JKIA.

. Temporal Rainfall variation per month

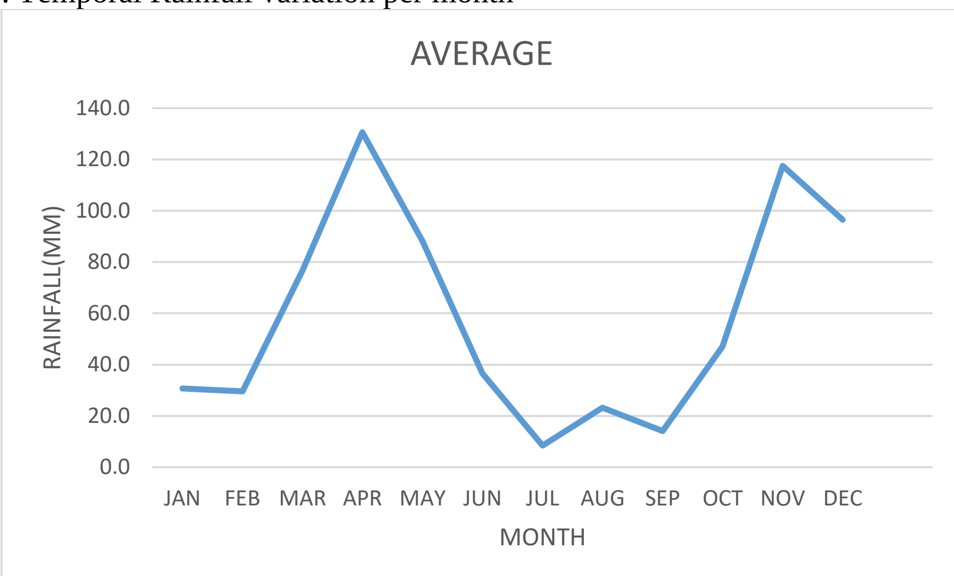

Figure 12. Rainfall variation per month

The graph above, there was decrease in rainfall in the months of December January to February (DJF) season. Rainfall then began to increase in May April and March (MAM) season
From there, it began to decrease in June July August (JJA).In the season of September, October, November SON, rainfall experienced increases in JKIA

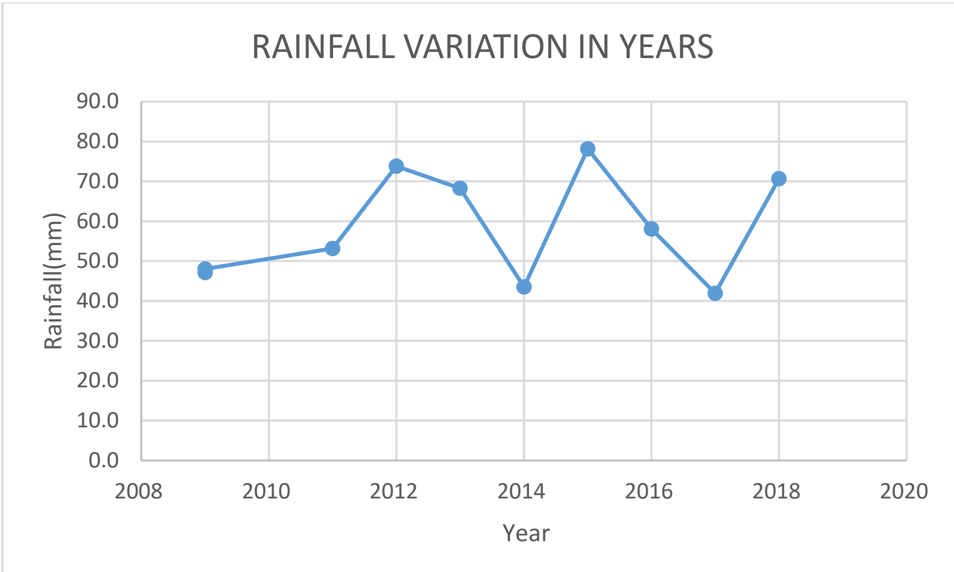

Figure13: Rainfall variation in years

. High rainfall received in 2015 and the least in 2017

4.4 HOMOGEINITY TEST

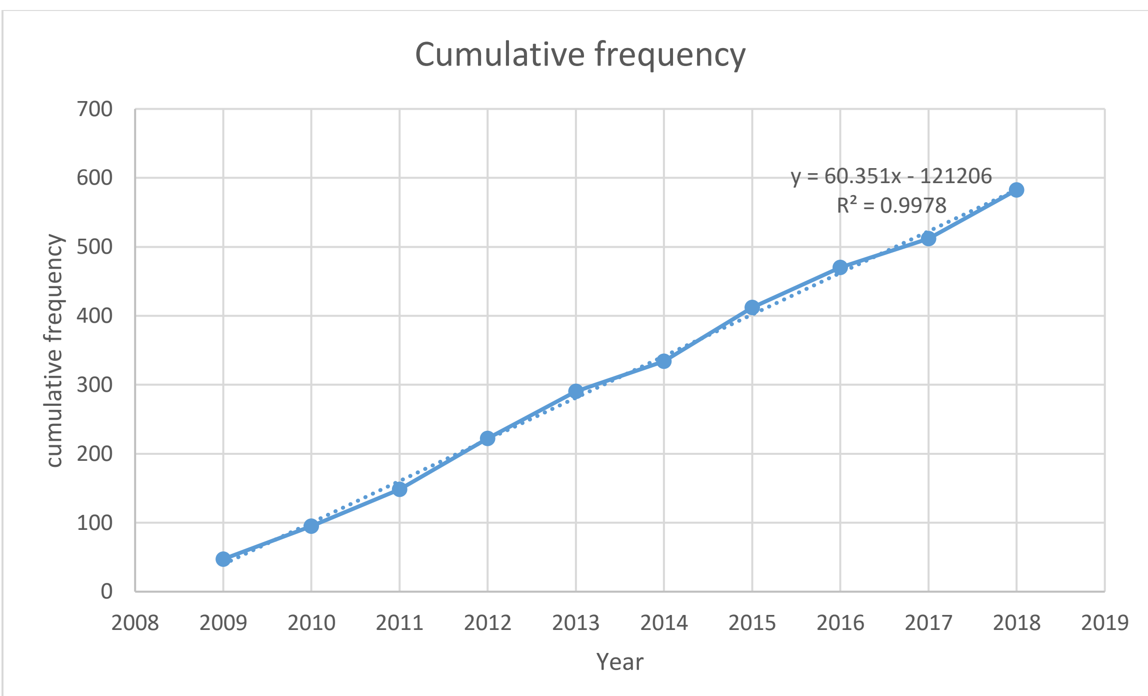

Figure 14: Rainfall variation over the years

The high R-squared value of 0.9978 suggests a strong linear relationship between year and cumulative frequency. This means that the variable increases at an approximately constant rate over time.

$Y=60.351x - 121206$
$R^2 = 0.9978$

4.5 ANNUAL RAINFALL AND TEMPERATURE VARIATION

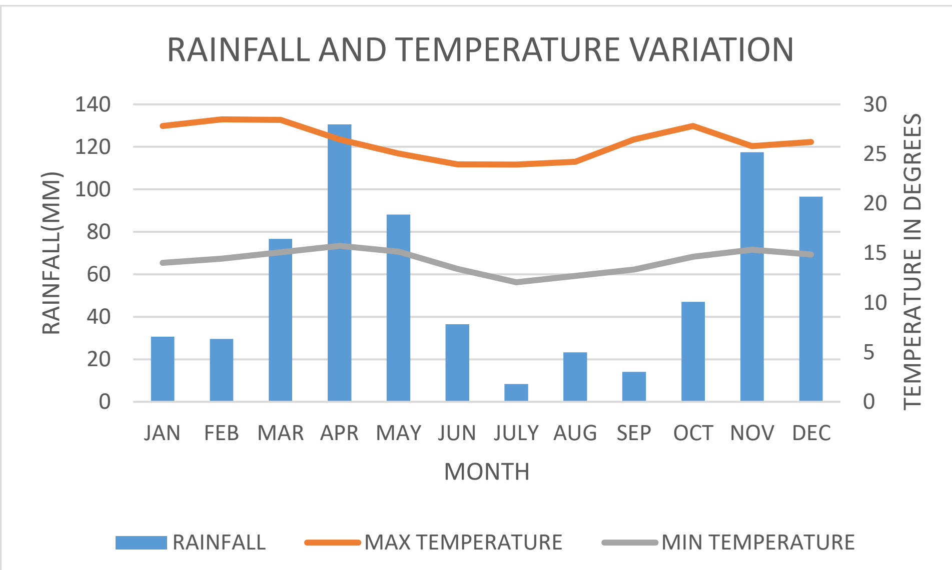

Figure 15: Annual rainfall and temperature variation

The above graph shows a positive correlation between rainfall and temperature. The rainfall is highest in April and November, and lowest in July and September. The temperature is highest in February and October, and lowest in July and August.

<u>t-Test: Paired Two Sample for Means for total rainfall and temperature.</u>

	Variable 1	*Variable 2*
Mean	696.88	701.36
Variance	21437.09	37230.29
Observations	5	5

Pearson Correlation	-0.21408
Hypothesized Mean Difference	0
df	4
t Stat	-0.03766
P(T<=t) one-tail	0.485882
t Critical one-tail	2.131847
P(T<=t) two-tail	0.971765
t Critical two-tail	2.776445

From the summery above the mean is increasing significantly. The Pearson Correlation value is -0.21408 this indicates a weak negative correlation between the two variables, if one value of one variable increases, the value of the other variable tends to decrease. For the t statistic the p-value is so high therefore we cannot reject the null hypothesis the typical is usually 0.05.

In general according to the objective, of fog, temperature and rain has an impact on aviation operation in Jomo Kenyatta Airport this as seen on data analysis. Fog variation with temperature showing cancellation and giving chance to other parameters

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

This chapter contains conclusions made from the research and recommendations.

5.1 CONCLUSION

5.1.1 FOG

In 2010 fog occurrence was most frequent while fog in 2009 it was least, likely due unavailability of fog forming condition. Fog is most common between March and April with April having the greatest number of days and August having the fewest. There is a rise in fog occurrences during September, October and November (SON) and a decrease in June, July and August (JJA) as well as December, January and February (DJF).

5.1.2 MAXIMUM TEMPERATURE

Temperature increases from December to February reaching its peak in February at 28.4°C. The decreases is experienced from March to May to around 23.9°C before rising from June to August with an increase in September and October before dropping once more. The lowest temperature was recorded in 2018 while the highest was noted in 2017.

5.1.3 MINIMUM TEMPERATURE

The coldest months are December, January and February (DJF) whereas the warmest months are July and August with July being the month within that period. There is a temperature decrease from March to May (MAM) and an increase, during September, October and November (SON). The lowest minimum temperature was recorded in 2010 while the highest occurred in 2017.

5.2 RECOMMENDATION

Aircrafts should carry additional contingency fuel for emergency purposes.

Install cutting edge visibility systems at JKIA to enhance visibility during fog events. This could include infrared cameras, LIDAR systems, or other technologies that can penetrate fog and provide pilots with clear visual guidance.

AIRMETs and weather depiction charts should be issued by the National Weather Service to the aircraft crew and these will help then detect fog areas and where IFR will be necessary.

Building of longer runways to increase the aircraft acceleration during takeoff.

Training pilots to fly in low visibility conditions this includes the use of instrument landing systems. This would equip them with the skills and confidence to navigate safely during fog events.

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