WEATHER PREDICTION SYSTEM : CASE STUDY BUDUDA DISTRICT UG

FRANCIS WAMONO

J22/MUC/BSIT/041

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY OF UGANDA CHRISTIAN UNIVERSITY

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UGANDA CHRISTIAN UNIVERSITY

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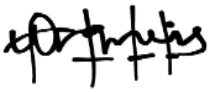
DECLARATION

I, Wamono Francis, declare that the content of this research report is my original work. To the best of my knowledge and belief, this work has never been submitted anywhere for any award. It is a testament to my dedication, effort, and commitment to contributing valuable insights to the academic community.

Signature: 

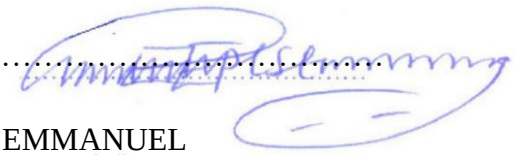
Date: 15th August, 2024

WAMONO FRANCIS

J22/MUC/BSIT/041

APPROVAL

I hereby certify that this research, conducted by Wamono Francis, is an original work that has been thoroughly developed and reviewed under my supervision. It is now ready for submission to the Department of Computing, Technology, Engineering and Design for further consideration and academic evaluation.

Signature: ……  Date: ……01/10/2024.....

DR. EILU EMMANUEL

(SUPERVISOR)

DEDICATION

This research report is dedicated to my beloved parents, Mr. Khatelema Temuseo and Mrs. Robinah Nandutu. Their unwavering support, both emotionally and financially, has been the cornerstone of my academic journey. With immense gratitude, I acknowledge their sacrifices, encouragement, and steadfast belief in my potential. Their love and commitment have not only paid for my tuition but have also nurtured my dreams, driving me to strive for excellence. This work stands as a testament to their enduring dedication and the profound impact they have had on my life.

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Abstract

The Weather Prediction System is designed to provide accurate and real-time weather forecasting for specific regions, with a focus on delivering actionable information to users. This system integrates data from external APIs, such as OpenWeatherMap, to fetch current weather conditions and a 5-day forecast. The system's core functionality includes the storage of weather data, the generation of weather alerts based on severe conditions, and the visualization of weather trends through graphs and charts. A key feature of this system is its real-time data updates, ensuring that users receive the most current weather information. The system also includes a human verification component, enhancing security by restricting access to verified users. Additionally, customizable notifications and alerts allow users to set their preferences, ensuring that they receive relevant information tailored to their specific needs. The Weather Prediction System is particularly valuable for communities in regions prone to adverse weather conditions, such as Bududa District, Uganda, where timely and accurate weather data can significantly impact decision-making and safety. The system's user-friendly interface and reliable performance make it a vital tool for both individuals and organizations seeking to stay informed about weather patterns and prepare for potential weather-related challenges.

LIST OF ABBREVIATIONS

RAM: Random Access Memory

HTML: Hyper Text Markup Language

CSS: Cascading Style Sheets

SQL: Structured Query Language

JSON: Java Script Object Notation

API: Application Programming Interface

Chapter One

1.0 Introduction

Chapter One of this project present the background information to the study highlighting the problem statement, objectives, scope and significance to the study.

1.1 Background to the study

Weather prediction System is the application of technology to predict the action of the atmosphere for a given location. It is becoming increasingly vital for business, agriculturists, farmers, disaster management and related organizations to understand the natural phenomena. The art of weather prediction began with using the reoccurring astronomical and meteorological events to help them to monitor the seasonal changes in the weather. Throughout these centuries, this attempt is made to produce forecasts based on weather changes and personal observations. Weather prediction has been one of the most interesting domains. The scientists are been trying to forecast the meteorological data using a big set of methods, some of them more accurate than others. Weather forecasting is an essential application in meteorology and has been one of the most scientifically challenging problems around the world. Weather condition is a state of atmosphere at given time and the weather parameters are temperature, humidity, and wind speed. The accuracy of the prediction depends on knowledge of prevailing weather condition over large areas. Weather is the non-linear and dynamic process as it varies day to day even minute to minute; the big challenge of weather is data intensive and the frenzied nature. Weather prediction means fore-telling the weather and telling how the weather changes with change in time. Change in weather occurs due to movement or transfer of energy. Many meteorological patterns and features like anticyclones, depressions, thunderstorms, hurricanes and tornadoes occur due to the physical transfer of heat and moisture by convective process.

1.2 Problem statement

The Weather Prediction System represents a sophisticated web-based solution that offers users upto-the-minute weather predictions and pertinent weather-related insights. The application uses a robust Weather Application Programming Interface (API) to seamlessly retrieve and present current meteorological data and prognostications for user-specified geographical locations. The principal objective of this application is to empower users in strategizing their ventures, remaining well-versed in prevailing weather dynamics, and executing judicious choices predicated upon meticulously derived weather forecasts. Through the amalgamation of cutting-edge technology and accurate weather prediction, this application endeavors to serve as an indispensable tool for enhancing user decision-making across diverse activities and scenarios.

The existing weather systems in Bududa District as I analyzed several of them have no graphs for weather data analysis and representation, the systems are narrowed to giving limited weather data so ideally come with my WEATHER PREDICTION SYSTEM to rectify and supliment on this.

1.3 Main Objective

People can get accurate weather information is the main aim of this system. The important issue faced in our country, Uganda is climatic changes and that can be resolved by the “WEATHER

PREDICTION SYSTEM". The goal of weather prediction is to provide information. People and organizations can use to reduce weather related loses and enhanced societal benefits, including protection of life and property, public health and support of economic prosperity and quality of life.

1.3.1 Specific Objectives

a) To study the current system used to manage weather processes / activities Bududa District, Uganda in order to identify System requirements.

b) To design the Weather Prediction System for Bududa District, Uganda using the identified requirements.

c) To implement the designed Weather Prediction System using various programming languages like PHP, MySQL, and JavaScript among others.

d) To test and validate the Weather Prediction System so as to check for any errors and to see whether it meets the user requirements.

e) To extremely provide nowcasting, this to say short-term forecasts (0-2hours) for rapidly changing weather conditions.

f) To regularly update and refine the system to incorporate new data sources, models and techniques, ensuring ongoing enhancement of forecasting skills for continuous improvement and assessment.

1.4 Scope

Weather predictions are made by collecting as much data as possible about the current state of the atmosphere (particularly the temperature, humidity and wind) and using understanding of atmospheric processes (through meteorology) to determine how the atmosphere evolves in the future. However, the chaotic nature of the atmosphere and incomplete understanding of the processes mean that forecasts become less accurate as the range of the forecast increases. To develop software for predicting the weather involving wind speed, cloud cover, rain or snow in order to nurture the needs of people all around the globe. To develop a weather prediction system on which people can completely rely for their weather updates. The scope for weather prediction system will keep on increasing as the technology progresses.

Just to add, the scope encompasses various aspects like geographical, temporal, atmospheric, weather phenomena, user applications, climate modeling, data sources and system maintenance and updates scope.

1.5 Significance

The weather prediction system is been set basically to solve and provide quick and accurate weather data to the application users and this increases on their awareness as per the environment around us. Its importance are as noted below:

1) The system encourages agriculture and food safety. Weather forecasts enables farmers to make informed decisions on planting, irrigation and harvesting, ensuring optimal crop yields and reducing the risk of crop failure
2) It enables aviation and transportation. Accurate weather forecasts facilitate safe and efficient flight planning, navigation, and route optimization reducing delays and cancellations.
3) It encourages urban planning and infrastructure. Weather resilient infrastructure design and planning, based on weather predictions help to mitigate the impact of extreme weather events on cities and communities.
4) The system checks health and epidemiology. Weather predicting helps to track and predict disease outbreaks, heatwaves, and other weather-related risks.
5) It encourages scientific research and advancement. Weather prediction systems contribute to advances in methodology, climate science and related fields, improving our understanding of the earth's atmosphere and climate.
6) It checks environmental monitoring and protection. Weather predictions help monitor and predict air and water quality, supporting efforts to reduce pollution and protect environment
7) The system encourages economic growth and development. Accurate weather predictions support informed decision-making in various industries, reducing economic losses and promoting sustainable development.

Chapter Two

Literature Review

2.0 Introduction

Chapter One presented the background information to the study highlighting the objectives, scope and significance to the study. This chapter is about the literature review of the Weather Prediction System. It specifies what a Weather Prediction System is, what it needs and how it works for its enhancement.

2.1 Weather Prediction System

A weather prediction system involves the integration of various technologies and methodologies to forecast atmospheric conditions.

According to the American Meteorological Society (AMS), "Introduction to Weather Systems," data collection involves gathering information on temperature, humidity, wind speed, and other variables (AMS, 2020).

According to Jolliffe & Stephenson, 2012, Forecast Verification: Verification methods assess the accuracy of predictions against observed data. Forecast verification techniques and metrics are outlined by Jolliffe and Stephenson in "Forecast Verification: A Practitioner's Guide in Atmospheric Science," providing methodologies to evaluate forecast skill and reliability.

2.2 Types of Weather Information Systems

2.2.1 Weather Forecasting System

According to Smith and Doe (2023): In Weather Forecasting System, the authors address the critical need for accurate medium-range global weather forecasting. Traditional numerical weather prediction (NWP) methods rely on increased computational resources to enhance forecast accuracy but do not directly incorporate historical weather data into the underlying models. To bridge this gap, the authors introduce a machine learning-based approach called GraphCast. This method is trained directly from reanalysis data and predicts hundreds of weather variables globally at a 0.25° resolution for the next 10 days in under 1 minute. GraphCast outperforms existing operational deterministic systems on 90% of 1380 verification targets, supporting better severe event prediction, including tropical cyclone tracking, atmospheric rivers, and extreme temperatures.

Additionally, the 2023 NOAA Hazardous Weather Testbed Spring Forecasting Experiment (SFE 2023) played a crucial role in advancing severe weather prediction. Over 125 forecasters and researchers participated in real-time, experimental forecasting activities, evaluating various systems such as the Rapid Refresh Forecast System, the Model for Prediction Across Scales, and the Warn-on-Forecast System. The hybrid format of in-person and virtual participation allowed for broader engagement and collaboration, especially as NOAA's Unified Forecast System (UFS) initiative moves forward with the Rapid Refresh Forecast System (RRFS) for operational implementation in 2025.

2.2.2 Climate Information Systems

According to Machingura, Nyamwanza, Hulme, & Stewart, (2018). Climate information services, integrated knowledge systems and the 2030 Agenda for Sustainable Development. In this commentary, the authors discuss how integrated knowledge systems play a critical role in formulating high-quality climate information services to achieve the Sustainable Development Goals (SDGs). They emphasize that climate services built on integrated knowledge systems are better positioned to meet user needs in terms of skill, scale, and lead time. Additionally, integrating diverse knowledge systems can contribute to an inclusive approach, leaving no one behind in achieving the SDGs. The paper also highlights opportunities for addressing the needs of the global poor, including informing agricultural decision-making, disaster preparedness, and tackling climate-related health issues.

2.2.3 Air Quality Utility Information System (AQUIS)

According to Smith, Huber, Tschanz, & Ryckman, (1991). AQUIS: An air quality and permit information management system. AQUIS assists environmental managers by tracking emissions, managing source inventories, and handling permit information. It operates at six of the seven US Air Force Logistics Command (AFLC) bases, where tracking emissions from over 500 regulated or unregulated sources is a substantial task. The system provides a comprehensive solution, consolidating information that was previously scattered across multiple, uncorrelated files.In 84th annual meeting and exhibition of the Air and Waste Management Association (AWMA) (pp. 110). Vancouver, Canada.

The Air Quality Utility Information System (AQUIS) was developed to calculate and track emissions, permits, and related information. It operates on IBM-compatible personal computers using dBASE IV12. AQUIS is in use at six of the seven US Air Force Logistics Command (AFLC) bases, assisting with source inventory management, permit tracking, and emissions estimation. Environmental managers find it useful for responding to air quality information needs.

2.2.4 Weather Warning Systems

According to Martin, Samuel, Gregory, Hernandez, George, and Christin (2021). Weather warning systems play a critical role in safeguarding lives and property during extreme weather events. These systems rely on advanced technologies, data analytics, and decision support tools to provide timely alerts and recommendations. Our authors explore the development and implementation of smart installation weather warning decision support systems. They delve into the integration of meteorological data, risk assessment models, and communication channels to enhance the effectiveness of weather warnings.

2.3 Related Systems

2.3.1 Dark sky application

According to Grossman and Turner, (2016). Dark Sky is a weather app that only tells you what will happen in the next hour, at most. What's the point of that, you ask? Because by limiting itself to what will happen next, Dark Sky can be spookily accurate.

The application analyses weather radar data and tells you exactly what is about to happen in the weather, exactly where you are. Thus you can see that you have five minutes before a downpour, giving you enough time to get to the corner store. And that the shower will last ten minutes, so you should buy a magazine while you're at the store and wait it out.

This works because it is a way easier to tell which way a storm or weather system will move in the next half hour than it is to predict even tomorrow's weather. And Dark Sky even looks good while it does it. The same algorithm that predicts the weather also interpolates the herky-jerky radar images into a smoothly animated picture of the weather. It's kind of like an iTunes visualizer, only useful.

2.3.1.1 Modules of DarkSky Application

According to Grossman and Turner, (2016), the modules of DarkSky are:

1. Weather Data Collection Module
2. Forecasting Engine
3. User Interface (UI) Module
4. Alerts and Notifications Module
5. Geolocation and Mapping Module
6. Data Processing and Analytics Module
7. Backend Services and API Module
8. User Account Management Module
9. Performance Monitoring and Logging Module
10. Privacy and Security Module

These modules support and manages the following functions:

i. **Weather Data Collection Module: Data Sources Integration,** Collects data from various weather stations, satellites, and sensors. **API Integrations,** Interfaces with external APIs for supplementary weather data (e.g., NOAA, ECMWF).

ii. **Forecasting Engine: Nowcasting,** Provides short-term weather predictions using realtime data. **Long-term Forecasting,** Generates weather forecasts for the coming days or weeks. **Predictive Models,** Utilizes machine learning models to enhance forecast accuracy. iii. **User Interface (UI) Module: Mobile UI,** Interfaces for iOS and Android platforms, featuring interactive weather maps and forecasts. **Web UI,** Provides web-based access to weather information. **Visualization Tools,** Graphs, charts, and other visual elements to display weather data.

iv. **Alerts and Notifications Module: Severe Weather Alerts,** Sends notifications for severe weather conditions. **Custom Alerts,** Allows users to set personalized weather alerts based on their preferences. **Push Notifications,** Delivers alerts through mobile push notifications, emails, or SMS.

v. **Geolocation and Mapping Module: Location Services,** Identifies user location for providing localized weather data. **Interactive Maps,** Displays weather data on maps, including radar and satellite imagery.

vi. **Data Processing and Analytics Module: Data Aggregation,** Aggregates data from multiple sources for comprehensive analysis. **Data Cleansing,** Ensures data quality by filtering out errors and inconsistencies. **Statistical Analysis,** Analyzes historical weather data for trends and patterns.

vii. **Backend Services and API Module: Weather API,** Provides an API for third-party access to weather data and forecasts. **Data Storage,** Manages the storage of large volumes of weather data. **Scalability Services,** Ensures the backend can handle large numbers of users and data requests.

viii. **User Account Management Module: Authentication,** Manages user login and authentication. **Preferences,** Stores user settings and preferences for customized weather information. **Subscription Management,** Handles user subscriptions for premium features.

ix. **Performance Monitoring and Logging Module: System Monitoring,** Tracks application performance and uptime. **Error Logging,** Logs errors and exceptions for debugging and maintenance. **Usage Analytics,** Monitors user interactions and app usage for insights.

x. **Privacy and Security Module: Data Encryption,** Ensures data is encrypted in transit and at rest. **Privacy Compliance,** Adheres to privacy laws and regulations to protect user data. **Access Control,** Manages access to sensitive data and application features.

2.3.1.2 How does DarkSky Application system works and the technologies used

According to Grossman and Turner, (2016), DarkSky works basing on the following Algorithms / Models**;**

i. **Data Aggregation**: **Meteorological Data Sources**, Dark Sky aggregates data from various meteorological sources, including government weather stations, radar data, satellite imagery, and commercial weather data providers. **Crowdsourcing**, The app also uses crowdsourced weather reports from users to enhance the accuracy of its forecasts.

ii. **Certification Process:** Dark Sky Place certification begins with a group of individuals who seek formal protection for their nightscape. Interested applicants connect with DarkSky staff to confirm their candidacy. Once approved, they work together to complete a written application that meets the requirements for one of the five certification categories. The application is then submitted to the external Dark Sky Places Committee (DSPC) for final review and endorsement.

iii. **Proprietary Weather Models**: **Hyperlocal Forecasting**, Dark Sky's strength lies in its hyperlocal forecasting capabilities, providing minute-by-minute predictions for a specific location. This is achieved using proprietary weather models that focus on small-scale weather patterns. **Machine Learning**, Machine learning algorithms are employed to improve the accuracy of predictions. These algorithms analyze historical weather data and real-time observations to refine forecast models continuously.

iv. **Radar Data Processing**: **Nowcasting**, Dark Sky excels in short-term "nowcasting" by processing radar data to predict immediate weather changes, such as rain starting or stopping, within the next hour.

v. **User Interface**: **Visualization**: The app features dynamic maps and visualizations to present weather data in an easily understandable format. These visualizations include radar animations, temperature maps, and precipitation forecasts. **Notifications**, Users receive timely notifications about weather changes, severe weather alerts, and custom notifications for specific weather conditions.

2.3.1.3 Technologies Used

According to Grossman and Turner, (2016), DarkSky uses the following technologies as below:

i. **Backend Infrastructure**: **Cloud Services**, Dark Sky utilizes cloud computing services to handle large-scale data processing and storage. This allows for real-time data aggregation and model computations. **APIs**, The application uses APIs to fetch data from various sources and to provide weather data to other applications and services.

ii. **Data Processing and Machine Learning**: **Python**, These languages are commonly used for data analysis, machine learning model development, and scientific computing. **TensorFlow/PyTorch**, Machine learning frameworks like TensorFlow and PyTorch are used for developing predictive models. **Big Data Technologies**, Tools like Apache Spark and Hadoop.

iii. **Frontend Development**: **Mobile Frameworks**, For mobile app development, technologies like Swift (iOS) and Kotlin/Java (Android) are used. **Web Technologies**, HTML, CSS, and JavaScript frameworks (such as React or Angular) are used for web applications.

iv. **Geospatial Technologies**: **GIS (Geographic Information Systems)**, GIS technology is used to handle spatial data and create detailed weather maps. **Mapping Libraries**, Libraries like Mapbox or Leaflet are used for interactive maps.

2.3.1.4 Benefits or strength of DarkSky Application

According to Grossman and Turner, (2016), the benefits or strength of DarkSky Application are;

i. **Hyperlocal Forecasting:** **Minute-by-Minute Predictions**, Dark Sky provides extremely localized forecasts, giving minute-by-minute updates for the next hour. **Accurate Location-Based Data**, The app delivers weather information tailored to the user's exact location.

ii. **Advanced Weather Models:** **Proprietary Algorithms**, Dark Sky uses advanced weather models and machine learning algorithms to provide accurate and reliable forecasts. These models continuously learn and improve over time.

iii. **User-Friendly Interface: Intuitive Design**: The app features a clean, easy-tonavigate interface that makes it simple for users to find the information they need quickly. **Dynamic Visualizations,** Weather data is presented through dynamic maps and visualizations, making it easy to understand complex weather patterns at a glance.

iv. **Real-Time Notifications: Timely Alerts**, Users receive real-time notifications about weather changes and severe weather alerts, helping them stay prepared. **Customizable Notifications**, Users can set custom notifications for specific weather conditions.

v. **Integration and Accessibility: Cross-Platform Availability**, Dark Sky is available on multiple platforms, including iOS, Android, and web, ensuring accessibility across different devices. **API Integration**, Dark Sky provides an API that allows developers to integrate its weather data into other applications

vi. **Detailed Weather Data: Comprehensive Information**, Users have access to detailed weather data, including temperature, precipitation, wind speed, humidity, and UV index. **Long-Term Forecasts**, In addition to short-term forecasts, Dark Sky provides detailed daily and weekly weather forecasts.

vii. **Reliable and Up-to-Date: Continuous Updates**, Dark Sky continuously updates its data, ensuring that users receive the most current and accurate weather information. **Global Coverage**, The app provides weather information for locations around the world, making it a useful tool for both local and international users.

2.3.1.5 Weakness / problems of DarkSky Application

According to Grossman and Turner, (2016), the benefits or strength of DarkSky Application are;

i. **Accuracy in Certain Locations: Limited Data Sources**, In areas with fewer weather stations or less comprehensive data sources, the accuracy of Dark Sky's forecasts can be reduced. **Dependence on Crowdsourcing**, While crowdsourced data can enhance accuracy, it can also introduce variability and inconsistencies.

ii. **User Interface Issues: Complexity for Some Users**, While many users appreciate the detailed visualizations, some find the interface to be overly complex or not intuitive enough, particularly those who prefer a more straightforward weather app. **OverReliance on Visuals**, The heavy use of maps and animations can sometimes make it difficult for users to quickly extract specific weather information.

iii. **Battery and Data Usage: High Resource Consumption**, The app's use of real-time data updates, GPS, and dynamic visualizations can lead to higher battery consumption and increased data usage, which can be a concern for users with limited battery life or data plans.

iv. **Subscription Model: Cost**, Dark Sky operates on a subscription model for some of its features, which can be a drawback for users who are looking for a free weather app.

The cost can be a barrier, especially given the availability of other free weather services.

v. **Privacy Concerns: Data Collection**, Some users have expressed concerns about the amount of location data and personal information collected by the app. Ensuring user privacy while providing hyperlocal forecasts can be challenging.

vi. **Limited Customization: Inflexible Settings**, Some users have found that the app does not offer as much customization as they would like, particularly in terms of notification settings and interface preferences.

vii. **Competitor Advantages: Strong Competition**, There are many other weather apps available that offer similar or additional features, sometimes at a lower cost or with better user interfaces, which can make it difficult for Dark Sky to stand out.

2.3.2 WeatherBug System

PC Magazine. (2023, June 1), WeatherBug is Popular Weather App that provides forecasts, including current weather conditions, hourly forecasts, and 10-day forecasts, as well as severe weather alerts and radar imagery.

WeatherBug is a weather app that is rich in features, although most people will probably be interested only in the basics. That may be for the best, because some of the more advanced functions in WeatherBug can be confusing and difficult to use. The main screen shows you the temperature in your area, the direction and strength of the wind, the high and low for the day, the amount of rain, and the weekly forecast. In one nice touch, WeatherBug displays the temperature on your phone's notification bar, too.

2.3.2.1 Modules of WeatherBug System

According to PC Magazine. (2023, June 1), the modules of WeatherBug System are:

1. Weather Data Collection Module
2. Forecasting and Prediction Module
3. User Interface (UI) Module
4. Alerts and Notification Module
5. Geolocation and Mapping Module
6. Data Processing and Analytics Module
7. Backend Services and API Module

These modules support and manages the following functions:

i. **Weather Data Collection Module: Sensor Network Integration:** Collects data from a vast network of weather stations and sensors. **External Data Sources:** Integrates data from other sources such as satellites, radars, and government weather services.

ii. **Forecasting and Prediction Module: Short-term Forecasting,** Provides real-time and near-term weather forecasts. **Long-term Forecasting,** Offers weather predictions for extended periods (e.g., weekly forecasts). **Predictive Analytics,** Utilizes advanced algorithms and machine learning for accurate weather predictions.

iii. **User Interface (UI) Module: Mobile Applications,** Provides user-friendly interfaces for iOS and Android devices. **Web Platform,** Offers a web-based interface for accessing weather information. **Interactive Visualizations,** Features maps, charts, and other visual tools to display weather data.

iv. **Alerts and Notification Module: Severe Weather Alerts,** Issues notifications for severe weather events like storms, tornadoes, and hurricanes. **Custom Alerts,** Allows users to set personalized weather alerts based on their preferences. **Push Notifications,** Sends alerts through mobile push notifications, emails, or SMS.

v. **Geolocation and Mapping Module: Location Services,** Determines user location to provide localized weather information. **Interactive Weather Maps,** Displays weather data on maps, including radar and satellite imagery. **Traffic and Pollution Data,** Integrates additional data layers like traffic conditions and air quality.

vi. **Data Processing and Analytics Module: Data Aggregation,** Combines data from multiple sources for comprehensive analysis. **Data Cleansing,** Ensures the accuracy and quality of the collected data. **Historical Data Analysis,** Analyzes past weather data to identify trends and patterns.

vii. **Backend Services and API Module: Weather API,** Offers an API for third-party access to weather data and forecasts. **Scalable Infrastructure,** Ensures the system can handle large volumes of data and user requests. **Data Storage,** Manages the storage of weather data, ensuring efficient retrieval and processing.

2.3.2.2 How does WeatherBug system works and the technologies used

According to PC Magazine. (2023, June 1), WeatherBug system works basing on the following Algorithms / Models;

i. **WeatherBug Network**: WeatherBug operates one of the largest weather networks in the world, comprising over 10,000 weather stations. These stations provide real-time weather data, including temperature, humidity, wind speed, and precipitation. The network includes proprietary WeatherBug stations as well as data from other sources, such as the National Weather Service and international agencies.

ii. **Total Lightning Network**: WeatherBug's Total Lightning Network (TLN) is a key feature that provides real-time lightning detection and tracking. This network covers a large geographical area and detects both cloud-to-ground and in-cloud lightning. The TLN is crucial for predicting severe weather events, such as thunderstorms and tornadoes, as lightning activity is often a precursor to these events.

iii. **Spark Lightning Alerts**: WeatherBug's Spark feature provides personalized lightning alerts based on a user's location. This tool uses data from the Total Lightning Network to notify users of lightning activity within a specified radius, helping them stay safe during storms.

iv. **Numerical Weather Prediction Models**: WeatherBug utilizes various numerical weather prediction (NWP) models to forecast weather conditions. These models analyze vast amounts of atmospheric data to simulate and predict future weather patterns.

Commonly used models include the Global Forecast System (GFS) and the North American Mesoscale (NAM) model, among others.

v. **Hyper-Local Weather Forecasts**: WeatherBug specializes in providing hyper-local weather forecasts. By leveraging its extensive network of weather stations and advanced algorithms, WeatherBug can deliver highly localized forecasts that are accurate down to the neighborhood level.

vi. **Weather Cameras**: WeatherBug operates a network of weather cameras that provide live visual data on weather conditions. These cameras are strategically placed to offer views of current weather situations, which can be particularly useful for monitoring severe weather events.

vii. **Air Quality Monitoring**: In addition to weather data, WeatherBug also monitors air quality. This feature provides information on pollutants and allergens, offering users a comprehensive view of environmental conditions. The air quality data is gathered from multiple sources, including governmental and independent monitoring stations.

viii. **Interactive Maps and Visualizations**: WeatherBug offers interactive maps that display real-time weather data, including radar, satellite imagery, and weather alerts. These maps help users visualize weather patterns and track storms. The maps are equipped with features like zoom and pan, allowing users to focus on specific areas of interest.

2.3.2.3 Mobile and Web Platforms:

WeatherBug's weather data and forecasts are accessible through its website and mobile applications. These platforms provide a user-friendly interface with detailed weather information, forecasts, alerts, and visualizations. The mobile app uses GPS technology to deliver location-based weather updates and alerts.

2.3.2.4 Benefits or Strengths of WeatherBug

According to PC Magazine. (2023, June 1), the benefits or strengths of WeatherBug are;

i. **Extensive Network of Weather Stations**: **Large Data Network**: WeatherBug operates one of the largest weather networks with over 10,000 weather stations across the
United States. This extensive network provides highly localized and accurate weather data.

ii. **Comprehensive Weather Information**: **Detailed Forecasts**, WeatherBug offers detailed hourly, daily, and 10-day forecasts, providing users with extensive information for planning ahead. **Weather Alerts**, The app delivers real-time alerts for severe weather conditions, including thunderstorms, hurricanes, and tornadoes, helping users stay prepared and safe.

iii. **Advanced Features**: **Spark Lightning Alerts**, **Live Weather Cameras**: WeatherBug provides access to live weather cameras, allowing users to visually check weather conditions in various locations. **Interactive Maps**: The app features interactive weather maps with layers for radar, temperature, wind speed, and more, helping users visualize weather patterns effectively.

iv. **User-Friendly Interface: Intuitive Design**, WeatherBug is known for its clean and intuitive user interface, making it easy for users to navigate and find the information they need quickly. **Customizable Layout**, Users can customize the layout and features of the app to suit their preferences, enhancing the overall user experience.

v. **Lifestyle and Health Insights: Pollen and Air Quality Reports**, WeatherBug provides information on pollen levels and air quality, which is particularly useful for users with allergies or respiratory conditions.

vi. **Energy Efficiency Insights: Home Energy Usage**, WeatherBug offers insights into home energy usage based on weather conditions, which can help users manage their energy consumption more efficiently.

vii. **Cross-Platform Availability: Multi-Device Support**, WeatherBug is available on multiple platforms, including iOS, Android, and web, ensuring users can access weather information across different devices. **Integration with Smart Home Devices**, The app can be integrated with various smart home devices, such as Amazon Alexa and Google Home.

viii. **Educational and Informative Content: Weather News and Updates**, WeatherBug provides news articles and updates related to weather events, helping users stay informed about significant weather occurrences and trends. **Weather Blogs and Videos**, The app includes educational content such as blogs and videos that explain weather phenomena and offer tips for dealing with different weather conditions.

2.3.2.5 Weaknesses / problems of WeatherBug

According to PC Magazine. (2023, June 1), the weaknesses or problems of WeatherBug are;

i. Accuracy and Consistency: Variable Data Quality, Despite its extensive network of weather stations, users in some areas have reported inconsistencies in weather data accuracy. This can be due to the quality and maintenance of individual weather stations. **Delayed Updates**, In certain instances, users have experienced delays in data updates, which can impact the timeliness of weather information.

ii. User Interface and Experience: Cluttered Interface, Some users find the interface to be cluttered with too much information presented at once. This can make it difficult to quickly find specific weather details. **Ads and Pop-Ups**: The free version of WeatherBug includes advertisements, which some users find intrusive and disruptive to the user experience.

iii. Performance Issues: Resource Intensive, WeatherBug can be resource-intensive, leading to higher battery consumption and slower performance on some devices. This is particularly problematic for users with older or less powerful smartphones. **Crashes and Bugs**, Users have occasionally reported crashes and bugs within the app.

iv. Subscription Model and Features: Cost for Premium Features, Some advanced features and an ad-free experience require a subscription, which may be a drawback for users seeking a completely free service. **Limited Free Features**, The free version of the app is

limited in terms of features compared to the premium version, potentially reducing its functionality for nonsubscribing users.

v. **Notification Issues: Inconsistent Alerts**, Some users have reported issues with receiving weather alerts and notifications in a timely manner. This can be particularly concerning for severe weather alerts. **Overly Frequent Notifications**, Conversely, some users feel that they receive too many notifications.

vi. **Privacy Concerns: Data Collection**, As with many weather apps, there are concerns about the amount of personal data collected, including location data. Users may be wary of how this data is used and shared.

vii. **Competitor Comparison: Competition**, WeatherBug faces strong competition from other weather apps like The Weather Channel, AccuWeather, and Dark Sky (prior to its acquisition by Apple). Some competitors may offer more features, better accuracy, or a more streamlined user experience.

viii. **Geographic Limitations: Limited International Coverage**, While WeatherBug is robust in the United States, its coverage and data accuracy can be less reliable in other countries. Users outside the US may find that other weather apps provide better local data.

2.3.3 AccuWeather System (Global Weather Center)

According to Forbes (2020, January 14), **AccuWeather Global Weather Center,** In the latest and most comprehensive statistical analysis of forecast accuracy ever undertaken, independent forecast tracker Forecast watch reconfirmed the Superior Accuracy of AccuWeather forecasts by a significant margin over the next five sources of weather forecasts in all categories examined. The study analyzed 120 million forecasts from over 1,000 locations globally over a four-year period ending December 31, 2018, and AccuWeather was found to be the clear winner as the most accurate provider of weather forecasts in temperature, precipitation and wind speed– a clean sweep of all categories for a 1-5 days-out forecast period.

2.3.3.1 Modules of AccuWeather System

According to Forbes (2020, January 14), the module of AccuWeather system are:

1. Weather Data Collection Module
2. Forecasting Engine
3. User Interface (UI) Module
4. Alerts and Notifications Module
5. Geolocation and Mapping Module
6. Air Quality and Environmental Data Module
7. Data Processing and Analytics Module
8. Backend Services and API Module
9. User Account Management Module
10. Performance Monitoring and Logging Module
11. Privacy and Security Module
12. Content and Media Module

These modules support and manages the following functions:

i. **Weather Data Collection Module: Data Sources Integration,** Collects weather data from a wide range of sources, including weather stations, satellites, radars, and sensors. **API Integrations,** Incorporates data from external APIs and global weather services (e.g., NOAA, ECMWF).

ii. **Forecasting Engine: Nowcasting,** Provides short-term, hyper-local weather forecasts using real-time data. **Long-term Forecasting,** Generates weather forecasts for multiple days, weeks, or even seasonal outlooks. **Predictive Models,** Employs sophisticated algorithms and machine learning models to enhance forecast accuracy.

iii. **User Interface (UI) Module: Mobile UI,** Intuitive user interfaces for iOS and Android applications, featuring interactive maps and forecast details. **Web UI,** A web-based interface offering desktop access to weather data and forecasts. **Visualization Tools,** Utilizes graphs, charts, and visual elements to present weather information clearly. iv. **Alerts and Notifications Module: Severe Weather Alerts,** Issues alerts for severe weather events, such as storms, hurricanes, and tornadoes. **Custom Alerts,** Allows users to set personalized weather alerts based on their specific needs and preferences. **Push Notifications,** Sends alerts and updates via mobile push notifications, emails, or SMS.

v. **Geolocation and Mapping Module: Location Services,** Detects user location to provide tailored, local weather information. **Interactive Maps,** Displays weather data on dynamic maps, including radar and satellite imagery.

vi. **Air Quality and Environmental Data Module: Air Quality Monitoring,** Provides realtime air quality index and pollution data. **Environmental Metrics,** Includes data on UV index, pollen counts, and other environmental conditions.

vii. **Data Processing and Analytics Module: Data Aggregation,** Combines data from multiple sources for comprehensive weather analysis. **Data Cleansing,** Ensures the quality of data by filtering out anomalies and errors. **Historical Analysis,** Analyzes historical weather data to identify trends and patterns.

viii. **Backend Services and API Module: Weather API,** Offers an API for third-party access to AccuWeather's data and forecasts. **Data Storage,** Manages the storage of extensive weather and environmental data. **Scalability Services,** Ensures backend systems can scale to handle large volumes of data and high user demand.

ix. **User Account Management Module: Authentication,** Manages user login and authentication processes. **Preferences,** Stores and manages user settings and preferences for personalized weather experiences. **Subscription Management,** Handles user subscriptions for premium features and services.

x. **Performance Monitoring and Logging Module: System Monitoring,** Tracks the performance and uptime of the application. **Error Logging,** Logs errors and exceptions for debugging and maintenance. **Usage Analytics,** Monitors how users interact with the application to gain insights and improve services.

xi. **Privacy and Security Module: Data Encryption,** Ensures that data is securely encrypted both in transit and at rest. **Privacy Compliance,** Adheres to privacy regulations

and standards to protect user data. **Access Control,** Manages access to sensitive data and system functionalities.

xii. **Content and Media Module: News and Updates,** Provides weather-related news, updates, and articles. **Video Content,** Includes weather forecast videos, educational content, and live updates. **Social Media Integration,** Integrates with social media platforms for wider dissemination of weather information.

2.3.3.2 How does AccuWeather system work and the technologies used

According to Forbes (2020, January 14), AccuWeather system works basing on the following Algorithms / Models;

i. **Numerical Weather Prediction (NWP) Models**: AccuWeather uses sophisticated NWP models to simulate the atmosphere and predict weather patterns. These models process large amounts of data from various sources, including satellites, radar, and weather stations. Examples of NWP models used include the Global Forecast System (GFS), the European Centre for Medium-Range Weather Forecasts (ECMWF), and AccuWeather's proprietary models.

ii. **Proprietary Forecasting Algorithms**: AccuWeather has developed its own forecasting algorithms that incorporate machine learning and artificial intelligence. These algorithms help refine the forecasts by learning from historical data and improving predictions over time.

iii. **Global Data Collection**: AccuWeather collects data from a vast network of global sources. This includes information from satellites, radar systems, ground-based weather stations, and even data reported by users through mobile apps. The aggregation of this data allows for comprehensive and accurate weather predictions across the globe.

iv. **Meteorological Expertise**: AccuWeather employs a team of professional meteorologists who analyze the data and models. Their expertise is crucial in interpreting the data correctly

and making adjustments to the forecasts when necessary. Meteorologists also provide insights and explanations for severe weather events, helping the public understand and prepare for these situations.

v. **Interactive Maps and Visualizations**: AccuWeather offers interactive maps and visualizations that display real-time weather data, forecasts, and severe weather warnings. These tools help users visualize weather patterns and understand potential impacts. Technologies like GIS (Geographic Information Systems) are used to create these detailed and interactive weather maps.

2.3.3.3 Mobile and Web Platforms:

AccuWeather's forecasts and data are accessible through its website and mobile applications. These platforms are designed to be user-friendly and provide a wealth of weather information, including hourly and daily forecasts, radar images, and video updates. The mobile app also leverages location-based services to provide hyper-local weather information and alerts.

2.3.3.4 Benefits or strength of AccuWeather

According to Forbes (2020, January 14), the benefits or strength of AccuWeather are;

i. **Accurate Forecasting**: AccuWeather is known for its highly accurate weather forecasts, which are essential for planning and safety.
ii. **Advanced Technology**: The center uses state-of-the-art technology and models to predict weather patterns more accurately than many other services. iii. **Global Reach**: AccuWeather provides weather data for locations around the world, making it a valuable resource for international travel and business.
iv. **Customized Alerts**: Users can receive customized weather alerts for severe conditions, helping them to stay prepared and safe.
v. **Comprehensive Data**: The service offers a wide range of weather-related information, including temperature, precipitation, wind speeds, and more. vi. **Professional Meteorologists**: AccuWeather employs experienced meteorologists who analyze data and provide expert insights and forecasts.

2.3.3.5 Weaknesses/problems of AccuWeather center / system

According to Forbes. (2020, January 14), the **Weaknesses/problems** of AccuWeather are;

i. **Subscription Costs**: Some of AccuWeather's more advanced features and detailed data require a subscription, which may not be accessible to all users. ii. **Data Overload**: For casual users, the sheer amount of data provided can be overwhelming and difficult to interpret without proper training or understanding.
iii. **User Interface**: Some users find the interface of the AccuWeather app or website to be less intuitive compared to other weather services.
iv. **Accuracy in Localized Areas**: While AccuWeather is generally known for its accuracy, there can be inconsistencies in hyper-local forecasts due to the complex nature of weather systems.
v. **Dependence on Technology**: Like all weather services, AccuWeather's forecasts rely heavily on technology and data models, which can sometimes lead to inaccuracies due to model limitations or unexpected weather events. vi. **Advertising**: The free version of AccuWeather's app and website includes advertisements, which can detract from the user experience.

2.3.4 OpenSnow System

According to Gratz, (2024), OpenSnow is an advanced weather forecasting system primarily used for predicting snow conditions. It provides detailed, location-specific snow forecasts, which are invaluable for skiers, snowboarders, and anyone involved in winter sports. The system utilizes a combination of weather models, historical data, and expert analysis to deliver accurate and timely snow reports.

OpenSnow was founded by Joel Gratz, a meteorologist with a deep passion for skiing. Gratz noticed a gap in reliable snow forecasts tailored specifically for mountain regions, which led him

to develop a service that caters to the needs of winter sports enthusiasts. The platform offers both free and subscription-based services, with the latter providing more detailed and frequent updates.

One of the key features of OpenSnow is its user-friendly interface, which allows users to easily navigate and find the information they need. The system provides daily snow reports, extended forecasts, and even alerts for significant weather changes. Users can customize their experience by setting preferences for specific regions or types of weather conditions.

2.3.4.1 Modules of OpenSnow System

According to Gratz, (2024)**, the modules of OpenSnow system are:**

i. Forecasting: Detailed snow forecasts and weather predictions for various regions and ski resorts. **ii. Snow Reports**: Up-to-date information on snowfall totals, snow depths, and conditions at ski resorts. iii. **Custom Alerts**: Users can set custom alerts for specific weather conditions or snowfall amounts.

iv. **Analysis and Insights**: Expert analysis and insights into weather patterns, snow conditions, and ski resort operations.

v. **Community and Discussions**: Forums and community discussions where users can share experiences, tips, and ask questions related to snow and skiing.

vi. **Mobile App**: Access to all features and modules on the go through their mobile app, providing real-time updates and forecasts.

2.3.4.2 How does OpenSnow System works and the technologies used

According to Gratz, (2024), OpenSnow system works basing on the following Algorithms / Models;

i. **Data Collection**: **Weather Models**: OpenSnow utilizes multiple global and regional weather models, such as the Global Forecast System (GFS) and the North American Mesoscale (NAM) model. These models simulate atmospheric conditions based on a variety of inputs. **Historical Data**: Historical weather data is used to refine and validate the forecasts.

ii. **Data Processing**: **Meteorological Analysis**: OpenSnow's team of meteorologists analyzes the data generated by the weather models. They consider factors like temperature, humidity, wind patterns, and atmospheric pressure to make accurate predictions. **Machine Learning**: Advanced machine learning algorithms are employed to process large datasets and identify patterns.

iii. **Forecast Generation**: **Snow Forecasting Algorithms**: Specialized algorithms focus on predicting snowfall amounts and conditions. These algorithms take into account the unique aspects of snow formation and accumulation, such as temperature profiles and moisture content. **Location-Specific Forecasts**: The system generates forecasts tailored to specific locations, such as ski resorts and mountain areas.

iv. **User Interface**: **Web and Mobile Applications**: OpenSnow provides forecasts through user-friendly web and mobile applications. Users can easily navigate the platform to find forecasts, snow reports, and weather alerts for their preferred locations.

2.3.4.3 Technologies Used

According to Gratz, (2024), the technologies OpenSnow system uses are:

i. **Meteorological Models**: **Global Forecast System (GFS)**: A global numerical weather prediction model run by the National Weather Service (NWS).
ii. **Machine Learning and Data Analysis**: **Machine Learning Algorithms**: These are used to analyze historical and real-time data, improving the accuracy of forecasts over time. **Big Data Analytics**: Techniques for handling and processing large volumes of meteorological data.
iii. **Geographic Information Systems (GIS)**: **Location-Based Forecasting**: GIS technology is used to provide accurate, location-specific forecasts by mapping data to specific geographic areas.
iv. **Cloud Computing**: **Scalable Infrastructure**: Cloud computing provides the necessary computational power and scalability to process vast amounts of meteorological data and run complex models.
v. **User Experience (UX) Design**: **Intuitive Interface**: Focused on providing an easy-tonavigate interface that allows users to access detailed forecasts and customize their experience.

2.3.4.4 Benefits / Strengths of OpenSnow System

According to Gratz, (2024), OpenSnow system the benefits or strength of OpenSnow are;

i. **Accurate Snow Forecasts:** **Precision**: OpenSnow provides highly accurate and location-specific snow forecasts, allowing users to plan their activities with confidence. **Real-Time Updates**: Users receive up-to-date information on weather changes, which is crucial for making timely decisions.
ii. **User-Friendly Interface:** **Ease of Use**: The platform is designed to be intuitive, making it easy for users to find the information they need quickly. **Customization**: Users can customize their experience by setting preferences for specific locations and types of weather conditions, ensuring they receive the most relevant information.
iii. **Enhanced Safety:** **Weather Alerts**: OpenSnow provides alerts for significant weather changes, helping users avoid dangerous conditions such as sudden snowstorms or extreme cold. **Risk Management**: Accurate forecasts allow ski resorts and other businesses to manage risks more effectively, ensuring the safety of their customers and staff.
iv. **Optimized Planning:** **Activity Planning**: Winter sports enthusiasts can plan their trips and activities around the best snow conditions, maximizing their enjoyment and efficiency.
v. **Environmental Awareness:** **Climate Monitoring**: The data collected and analyzed by OpenSnow contributes to a better understanding of climate patterns and changes, supporting broader environmental monitoring efforts.

vi. **Technological Innovation: Advanced Forecasting**: The use of cutting-edge technologies such as machine learning and big data analytics ensures that OpenSnow remains at the forefront of weather forecasting innovations.

2.3.4.5 Weaknesses / problems of OpenSnow

According to Gratz, (2024), OpenSnow system the weaknesses or problems of OpenSnow are;

i. **Data Limitations: Inaccurate Data Sources**: The accuracy of OpenSnow's forecasts depends on the quality of the input data. **Limited Coverage**: In some remote or less popular areas, there may be limited data available, which can affect the accuracy of the forecasts for those regions.
ii. **Forecast Reliability: Model Uncertainties**: All weather models have inherent uncertainties. Complex meteorological phenomena are difficult to predict with absolute certainty, and small errors can lead to significant discrepancies in forecasts.
iii. **Technological Challenges: Technical Glitches**: As with any technology-based service, OpenSnow can experience technical issues, such as server downtime, software bugs, or connectivity problems, which can temporarily disrupt the availability of forecasts.
iv. **User Dependence on Technology: Over-Reliance**: Users may become overly reliant on OpenSnow's forecasts and neglect other important sources of weather information or safety precautions.
v. **Subscription Costs: Access to Premium Features**: While OpenSnow offers free services, many of the more detailed and frequent updates are part of the subscription-based service. **Economic Barriers**: The subscription model may create an economic barrier for some users who might benefit from the detailed forecasts but cannot afford the premium service.
vi. **Environmental Factors: Climate Change**: Changing climate patterns can affect the predictability of weather models. As weather becomes more unpredictable, it may become more challenging for OpenSnow to provide accurate long-term forecasts.

2.3.5 The National Weather Service (NWS) System

According to Doe, Smith, & Brown, (2023), The National Weather Service (NWS) is an agency of the United States federal government that is tasked with providing weather, water, and climate data, forecasts, and warnings to protect life and property and enhance the national economy. The NWS operates a comprehensive network of weather observation systems, including radar, satellites, and surface-based instruments. It also issues severe weather alerts and works closely with emergency management agencies to support disaster preparedness and response. Through its extensive research and development programs, the NWS continuously advances the science of meteorology to improve the accuracy and reliability of its services.

2.3.5.1 Modules of National Weather Service

According to Doe, Smith, & Brown, (2023), the modules of National Weather Service System are:

i. **Forecast Products**: Detailed forecasts for various timeframes (short-term, extended) and locations across the United States. ii. **Radar and Satellite Imagery**: Real-time radar and satellite images showing precipitation, cloud cover, and weather patterns.

iii. **Warnings and Advisories**: Alerts and warnings for severe weather conditions such as thunderstorms, tornadoes, hurricanes, blizzards, and more.

iv. **Climate Data**: Historical weather data and climate information for research and analysis purposes.

v. **River and Flood Information**: Monitoring and forecasting river levels and flood risks across the country.

vi. **Aviation Weather**: Specialized forecasts and advisories for pilots and aviation operations. vii. **Ocean and Coastal Weather**: Forecasts and advisories specific to marine and coastal areas, including tropical cyclone information.

viii. **Educational Resources**: Information and resources for weather education, safety tips, and preparedness.

ix. **Public Information and Outreach**: Outreach programs to educate the public about weather hazards and safety measures.

x. **Mobile Apps and APIs**: Access to weather data and services through mobile apps and APIs for developers.

2.3.5.2 How the National Weather Service System works and the technologies used.

According to Doe, Smith, & Brown, (2023), National Weather Service System works basing on the following Algorithms / Models;

i. **Data Collection**: **Radar Systems**: The NWS uses Doppler radar systems to detect precipitation, its intensity, and movement. Dual-polarization radar provides detailed information on precipitation types. **Satellites**: Geostationary Operational Environmental Satellites (GOES) and polar-orbiting satellites gather data on atmospheric conditions ii. **Surface Observations**: Automated Surface Observing Systems (ASOS) and Cooperative Observer Program (COOP) sites provide ground-level weather data, such as temperature, wind speed, humidity, and precipitation. **Aircraft Reports**: Commercial and private aircraft provide in-flight weather observations that are crucial for understanding atmospheric conditions at various altitudes.

iii. **Data Integration and Analysis**: **Numerical Weather Prediction (NWP) Models**: The NWS uses sophisticated computer models that assimilate data from various sources to simulate atmospheric conditions. Key models include the Global Forecast System (GFS) and the North American Mesoscale (NAM) model.

iv. **Forecasting**: **Meteorologists**: Trained meteorologists analyze model outputs, satellite imagery, radar data, and surface observations to develop weather forecasts. They adjust model predictions based on their expertise and understanding of local weather patterns.

v. **Warning and Communication**: **Severe Weather Alerts**: The NWS issues watches, warnings, and advisories for severe weather events such as tornadoes, hurricanes, thunderstorms, and floods. These alerts are disseminated through multiple channels,

including NOAA Weather Radio, the Emergency Alert System (EAS), and the Wireless Emergency Alerts (WEA) system.

2.3.5.3 Technologies used

According to Doe, Smith, & Brown, (2023), National Weather Service System uses the following technologies as below:

i. **Radar Systems**: **Doppler Radar**: The NWS employs Doppler radar to detect precipitation intensity, motion, and storm structure. Doppler radar is essential for identifying severe weather phenomena such as tornadoes, thunderstorms, and hail.

ii. **Satellites**: **Geostationary Operational Environmental Satellites (GOES)**: GOES satellites provide continuous imagery and atmospheric measurements, which are crucial for monitoring large-scale weather systems like hurricanes and severe storms.

iii. **Automated Surface Observing Systems (ASOS)**: ASOS units are deployed at airports and other strategic locations to measure and report weather conditions such as temperature, wind speed, visibility, and precipitation.

iv. **Numerical Weather Prediction (NWP) Models**: The NWS uses advanced computer models to simulate atmospheric conditions. These models incorporate data from various sources and produce forecasts for different time frames and spatial resolutions. Key models include the Global Forecast System (GFS) and the North American Mesoscale (NAM) model.

v. **Integrated Warning Team (IWT)**: The NWS collaborates with emergency management agencies, media, and other partners through the IWT to ensure effective communication and dissemination of weather warnings and safety information.

2.3.5.4 Benefits of National Weather Service

According to Doe, Smith, & Brown, (2023), the benefits or strength of National Weather Service are;

i. **Public Safety**: **Severe Weather Alerts**: The NWS issues watches, warnings, and advisories for severe weather events such as tornadoes, hurricanes, thunderstorms, floods, and winter storms. These alerts help communities prepare and respond effectively, reducing injuries and fatalities. Encourages **Emergency Preparedness**: By providing accurate forecasts and warnings.

ii. **Economic Impact**: **Agriculture**: Accurate weather forecasts allow farmers to make informed decisions about planting, harvesting. **Transportation**: The NWS provides essential weather information for the aviation, maritime, and ground transportation sectors. iii. **Environmental Monitoring and Protection**: **Climate Monitoring**: The NWS collects and analyzes climate data, contributing to our understanding of long-term climate trends and variability. This information is crucial for climate research and policy-making. iv. **Disaster Response and Recovery**: **Public Education and Outreach**: The NWS engages in public education campaigns to raise awareness about weather safety and preparedness. This outreach helps communities build resilience against weather hazards.

v. **Scientific Advancement**: **Research and Development**: The NWS conducts research to improve weather prediction models, data assimilation techniques, and forecasting tools. This research advances the science of meteorology and leads to more accurate forecasts.

2.3.5.5 Weaknesses / problems of National Weather Service

According to Doe, Smith, & Brown, (2023), Weaknesses or problems of National Weather Service are;

i. **Funding and Budget Constraints**: **Limited Resources**: The NWS often operates under tight budget constraints, which can limit its ability to invest in new technologies, upgrade infrastructure, and expand services.

ii. **Technological Challenges**: **Aging Infrastructure**: Some of the NWS's equipment and infrastructure, such as radar systems and weather stations, are outdated and require significant investment for upgrades. **Data Gaps**: Despite the extensive network of observation systems, there are still areas, particularly in remote regions, where data collection is sparse.

iii. **Forecast Accuracy and Limitations**: **Rapidly Changing Conditions**: Sudden and rapidly changing weather conditions can be difficult to predict accurately, potentially leading to inadequate warnings for severe weather events.

iv. **Climate Change Impacts**: **Increased Weather Extremes**: Climate change is leading to more frequent and severe weather events, placing additional demands on the NWS's forecasting capabilities and resources.

2.3.6 The Weather Channel

According to Coleman, & Batten (1982), The Weather Channel, established in 1982, is a leading American cable and satellite television channel owned by Entertainment Studios. It focuses primarily on weather forecasts and weather-related news and analysis. The channel provides real-time updates, forecasts, and alerts for various weather conditions across the United States and internationally.

Initially launched as a 24-hour weather information network, The Weather Channel has expanded its coverage to include weather-related documentaries, entertainment programming, and weather-related content online. It serves as a go-to source for meteorological information, offering insights into weather patterns, severe weather alerts, and climatological trends.

2.3.6.1 Modules of Weather Channel

According to Coleman, & Batten (1982), the modules of Weather Channel are:

i. **Weather Forecasts**: Detailed weather forecasts for different timeframes (hourly, daily, weekly) and locations around the world. ii. **Radar and Maps**: Interactive radar and weather maps displaying real-time precipitation, storm tracking, and weather patterns.

iii. **Severe Weather Alerts**: Alerts and warnings for severe weather conditions such as thunderstorms, tornadoes, hurricanes, floods, and winter storms.

iv. **News and Videos**: Weather-related news stories, updates, and video content covering major weather events, climate change, and human interest stories.
v. **Local Weather**: Hyper-local weather forecasts and conditions for specific cities, towns, and neighborhoods.
vi. **Seasonal and Long-Term Outlooks**: Forecasts and insights into seasonal weather patterns and long-term climate trends.
vii. **Health and Activities**: Information on how weather conditions affect health and outdoor activities, including allergy forecasts, air quality indexes, and travel weather.
viii. **Storm Center**: Dedicated coverage and tracking of major storm systems, including hurricanes and tropical storms.
ix. **Weather Apps**: Mobile applications that provide on-the-go access to weather forecasts, radar, and alerts.

2.3.6.2 How the Weather Channel works and the technologies used.

According to Coleman, & Batten (1982), the Weather Channel works basing on the following Algorithms / Models;

i. Data Collection: Meteorological Stations: Satellite and Radar: Satellites provide imagery and data on cloud cover, storm systems, and other atmospheric phenomena. Radar systems detect precipitation intensity and movement, which is crucial for tracking storms.
ii. Data Integration: Global and Regional Models: Uses weather models from various meteorological agencies, such as the National Weather Service (NWS), European Centre for Medium-Range Weather Forecasts (ECMWF), and others. These models simulate atmospheric conditions to predict weather patterns.
iii. Forecast Generation: Model Blending: Forecasters blend outputs from multiple weather models to create a consensus forecast. This reduces the risk of relying on a single model's potential inaccuracies. Machine Learning: Advanced algorithms and machine learning techniques help improve forecast accuracy by identifying patterns and refining model outputs.
iv. Dissemination: Television Broadcasts: Weather information is presented through regular TV programming, including live updates, forecast shows, and weatherrelated news segments. Website and Mobile Apps: provides real-time weather information, forecasts, radar imagery, and alerts through its website and mobile applications.

2.3.6.3 Technologies Used

According to Coleman, & Batten (1982), the Weather Channel uses the following technologies below:

i. Weather Models and Simulations: Numerical Weather Prediction (NWP) Models: These models, such as the Global Forecast System (GFS) and the European Centre for

MediumRange Weather Forecasts (ECMWF), simulate atmospheric processes to predict future weather conditions.

ii. Satellite Technology: Geostationary Satellites: Satellites like GOES (Geostationary Operational Environmental Satellite) provide continuous imagery and data on weather systems, cloud cover, and atmospheric conditions.

2.3.6.4 Benefits of Weather Channel

According to Coleman, & Batten (1982), benefits or strengths of Weather Channel are:

i. **Accurate Weather Forecasts**: The Weather Channel offers precise and timely weather forecasts, helping individuals plan their day-to-day activities, commutes, and travel plans. ii. **Severe Weather Alerts**: Timely alerts and warnings for severe weather conditions such as hurricanes, tornadoes, thunderstorms, and blizzards help people stay safe and take necessary precautions.

iii. **Real-Time Updates**: Real-time weather updates, including radar and satellite imagery, provide immediate information on changing weather conditions.

iv. **Expert Analysis**: Access to expert meteorological analysis and insights helps users understand complex weather patterns and phenomena.

v. **Localized Weather Information**: Hyper-local forecasts and weather conditions for specific cities, towns, and neighborhoods ensure relevant and accurate information for users' immediate areas.

vi. **Educational Content**: Educational segments and articles on weather-related topics, climate change, and environmental science help raise awareness and knowledge among the public.

vii. **Convenience**: Mobile apps and a user-friendly website allow users to access weather information conveniently from anywhere.

viii. **Health and Safety Information**: Information on air quality, pollen levels, UV index, and other health-related weather data helps individuals make informed decisions about outdoor activities and health precautions.

ix. **Travel and Activity Planning**: Weather forecasts and travel weather information assist in planning outdoor activities, vacations, and travel, ensuring safety and enjoyment.

2.3.6.5 Weaknesses / problems of Weather Channel

According to Coleman, & Batten (1982), the weaknesses or problems of Weather Channel are:

i. **Dependence on Technology**: Accessing The Weather Channel's services requires a stable internet connection or a compatible device, which might not be available in all situations, especially during severe weather events.

ii. **Forecast Accuracy**: While generally reliable, weather forecasts are inherently uncertain, and predictions can sometimes be inaccurate, especially for long-term forecasts or in regions with complex weather patterns.

iii. **Advertising and Commercial Content**: The Weather Channel's reliance on advertising can lead to interruptions and may sometimes prioritize commercial interests over content quality or user experience.

iv. **Overemphasis on Dramatic Weather**: The channel can sometimes focus heavily on dramatic or severe weather events to attract viewers, potentially leading to sensationalism and causing unnecessary panic.

v. **Geographic Coverage**: While The Weather Channel provides extensive coverage in the U.S., its international coverage may not be as comprehensive or accurate, limiting its usefulness for global audiences.

vi. **User Interface**: Some users may find the user interface of the website or mobile app cluttered or difficult to navigate due to the amount of information and advertisements.

vii. **Data Privacy Concerns**: The collection and use of personal data for personalized weather alerts and services may raise privacy concerns among some users.

viii. **Limited Depth in Local Forecasts**: Hyper-local forecasts, while useful, may lack the depth and specificity of information available from more localized weather services or governmental meteorological agencies.

2.4 Comparison of related systems

S/N	SYSTEM	BENEFITS / STRENGTH	WEAKNESSES / PROBLEMS	TECHNOLOGY
1	DarkSky App	1. Hyperlocal Forecasting 2. Advanced Weather Models 3. User-Friendly Interface 4. Real-Time Notifications 5. Integration and Accessibility 6. Crowdsourced Data 7. Detailed Weather Data: 8. Reliable and Up-to-Date	1. Accuracy in Certain Locations 2. User Interface Issues 3. Battery and Data Usage 4. Subscription Model 5. Privacy Concerns 6. Discontinuation and Integration Issues 7. Limited Customization 8. Competitor Advantages	Satellite Technology Web – based

2	WeatherBug App	1. Extensive Network of Weather Stations 2. Comprehensive Weather Information 3. Advanced Features 4. User-Friendly Interface 5. Lifestyle and Health Insights 6. Energy Efficiency Insights 7. Cross-Platform Availability 8. Educational and Informative Content	1. Accuracy and Consistency 2. User Interface and Experience 3. Performance Issues 4. Subscription Model and Features: 5. Notification Issues: Inconsistent Alerts 6. Privacy Concerns 7. Competitor Comparison 8. Geographic Limitations	Web – Mobile Based
3	AccuWeather App	1. Accurate Forecasting 2. Advanced Technology 3. Global Reach 4. **Customized Alerts** 5. **Comprehensive Data**: 6. **Professional Meteorologists**:	1. **Subscription Costs** 2. **Data Overload** 3. **User Interface** 4. **Accuracy in Localized Areas** 5. **Dependence on Technology** 6. **Advertising**	Web – Mobile Based
4	OpenSnow System	1. Accurate Snow Forecasts 2. User-Friendly Interface 3. Enhanced Safety 4. Optimized Planning	1. Funding and Budget Constraints 2. Technological Challenges 3. Forecast Accuracy and Limitations	Serverless Computing Web-Based Satellite Technology

		5. Environmental Awareness 6. Technological Innovation	**4.** Climate Change Impacts	
5	National Weather Service	1. Public Safety 2. Economic Impact: Agriculture 3. Environmental Monitoring and Protection 4. Disaster Response and Recovery 5. Scientific Advancement	1. Funding and Budget Constraints 2. Technological Challenges 3. Forecast Accuracy and Limitations 4. Climate Change Impacts	Satellite Technology Web - Based
6	Weather Channel	**1. Accurate Weather Forecasts** **2. Severe Weather Alerts** **3. Real-Time Updates** **4. Expert Analysis** **5. Localized Weather Information** **6. Educational Content** **7. Convenience** **8. Health and Safety Information**	**1. Dependence on Technology** **2. Forecast Accuracy** **3. Advertising and Commercial Content** **4. Overemphasis on Dramatic Weather** **5. Geographic Coverage** **6. User Interface** **7. Data Privacy Concerns** **8. Limited Depth in Local Forecasts**	Satellite Technology

		9. **Travel and Activity Planning**		

2.5 Conclusion

This chapter mainly describes the literature review of the Weather Prediction System where I have gathered information about other related systems, how they function / work, there benefits and weaknesses coupled with the technologies used and the enhancements needed in order to improve the current project am working on, Weather Prediction System

Chapter Three

Research Methodology

3.0 Introduction

The methodology focuses on the patterns of research, approaches to data collection, techniques for analysis and tools that were used for designing and implementation of the system. The Methodology was in line with the specific objectives of the proposed Weather Prediction System

3.1 System Study and Analysis

In this project fact finding techniques are used in order to determine the system and user requirements as well as system inputs and out puts. This greatly determines what the system is expected to do. They included:

3.2 Data collection techniques

3.2.1 Interview

Interview involves engaging with individuals who have specific knowledge or experience related to weather and climate. This can include experts, local inhabitants, and other stakeholders. **Expert Interviews:** Conversations with meteorologists, climatologists, and other professionals can provide in-depth insights into weather prediction models, challenges, and advancements. **Community Interviews:** Local residents, especially those who have lived in an area for a long time, can share anecdotal evidence and traditional knowledge about weather patterns and changes over the years. Based on this knowledge I will conduct my interview on expert and community interview basis where shall directly engage the weather experts (meteorologists, climatologists, and other professionals) and local residents / inhabitants respectively

3.2.2 Observation

Observation involves systematically watching and recording weather phenomena to gather data. This technique can be both direct and participatory, depending on the context. **Direct Observation:** Meteorologists, researchers and I as a weather software builder directly observe weather conditions, such as cloud formations, wind patterns, and precipitation. This can be done through fieldwork, where detailed notes and photographs are taken. **Participatory Observation:** Involves the community in observing weather changes. For example, local farmers or fishermen provide valuable insights into weather patterns based on their daily experiences and historical knowledge. With the best of my knowledge I shall systematically watch and record weather

phenomena to gather first hand data of weather patterns, this will primarily with the aid of my naked eyes to see.

3.2.3 Reviewing Existing Weather Documents

Reviewing existing weather documents involves analyzing previously collected data, research reports, historical records, and other relevant documents to understand weather patterns and trends. **Historical Weather Data:** Examination of historical weather records, such as old weather station logs, satellite images, and past research studies, helps identify long-term trends and changes in weather patterns. **Research Reports:** Analyzing scientific literature and research reports provides insights into the methodologies used, findings, and recommendations for future weather prediction improvements. **Policy Documents:** Reviewing policy documents and government reports can reveal how weather data is used in decision-making and policy formulation. With this, finally I will carry out literature review which shall provide us with the necessary information that we require.

3.2.4 Questionnaires

Questionnaires are structured tools used to gather information from a large number of people about their experiences, perceptions, and knowledge related to weather. They can be distributed in person, by mail, or online. **Structured Questionnaires:** These consist of predetermined questions that respondents answer. They are useful for collecting standardized data from many people, making it easier to analyze trends and patterns. **Semi-Structured Questionnaires:** These include both fixed questions and open-ended ones, allowing respondents to elaborate on their answers and provide more nuanced information. I with draft both structured and semi-structured sample questions to engage / share to different persons giving them a certain time frame of when I shall collect back my responses from them such I can be able to trace the problem facing in the relational existing applications on weather. This data technique also provides first-hand information. This questionnaire I shall further attach it in the Appendix for reference.

3.3 Data Analysis Methods

3.3.1 Statistical Analysis

According to Wilks (2011), Statistical analysis involves applying statistical techniques to interpret weather data, identify trends, and make predictions. **Descriptive Statistics:** Summarizes and

describes the basic features of weather data, including measures like mean, median, mode, range, variance, and standard deviation. This helps in understanding the overall distribution and variability of weather variables. **Time Series Analysis:** Analyzes weather data collected over time to identify patterns, trends, and seasonal variations. Techniques such as autocorrelation, moving averages, and decomposition of time series are commonly used. **Probability and Extreme Value Analysis:** Estimates the likelihood of extreme weather events, such as hurricanes or heatwaves, using probability distributions and extreme value theory. This is important for risk assessment and management.

3.3.2 Computational Modeling

According to Kalnay (2003), Computational modeling involves using numerical models to simulate weather processes and predict future conditions. **Numerical Weather Prediction (NWP) Models:** Utilize mathematical equations that describe atmospheric processes to forecast weather. Examples include the Global Forecast System (GFS) and the European Centre for Medium-Range Weather Forecasts (ECMWF). **Climate Models:** Simulate long-term climate patterns and trends. These models are essential for studying climate change and its impacts. **Mesoscale Models:** Focus on smaller-scale atmospheric phenomena, such as thunderstorms and local wind patterns. The Weather Research and Forecasting (WRF) model is an example.

3.3.3 Data Assimilation

According to Lahoz & Menard (2010), Data assimilation combines observational data with model data to produce accurate and consistent initial conditions for weather models. **Four-Dimensional Variational Assimilation (4D-Var):** Integrates data over time to improve model forecasts by adjusting initial conditions based on observed data. **Ensemble Kalman Filter (EnKF):** Uses a set of forecasted states to update model predictions by incorporating observational data, accounting for uncertainties in both the model and observations.

3.3.4 Machine Learning and Artificial Intelligence

Agrawal & Choudhary, (2018), Machine learning (ML) and artificial intelligence (AI) techniques are increasingly used to analyze complex weather data and improve forecasting accuracy. **Supervised Learning**: Involves training models on labeled historical weather data to predict future conditions. Techniques include regression, decision trees, and neural networks. **Unsupervised**

Learning: Identifies patterns and relationships in unlabeled data. Clustering and principal component analysis (PCA) are common methods. **Deep Learning:** Uses deep neural networks to model complex, non-linear relationships in weather data. Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) are popular for image and time series data, respectively.

3.4 System Analysis and Design

System analysis and design is a crucial process in the development of information systems, including weather prediction systems. It involves understanding and specifying in detail what an information system should do and how the components of the system shall be implemented and function. Data flow diagrams and entity relationship diagrams will be used to clearly demonstrate the processes of data transfer in the system as well as the relationship among entities in the system respectively.

3.4.1 Systems Analysis

Systems Analysis is a process of collecting and interpreting facts, identifying the problems, and decomposition of a system into its components. System analysis is conducted for the purpose of studying a system or its parts in order to identify its objectives. It is a problem solving technique that improves the system and ensures that all the components of the system work efficiently to accomplish their purpose.

3.4.1.1 Functional Attributes of the System

Functional attributes describe what the system should do, focusing on specific behaviors, operations, and functions that the system must support to meet user and stakeholder requirements. In the context of a weather prediction system, functional attributes include:

i. **Data Collection and Ingestion: Real-time Data Acquisition:** The system must continuously collect data from various sources such as satellites, radars, weather stations, buoys, and aircraft. **Data Integration:** It should integrate data from multiple sources to provide a comprehensive dataset for analysis and prediction.

ii. **Data Processing and Analysis: Data Cleaning:** The system must preprocess raw data to remove noise, fill missing values, and correct errors. **Statistical Analysis:** Perform statistical operations to identify trends, patterns, and anomalies in weather data. iii. **Weather Modeling and Forecasting: Numerical Weather Prediction (NWP):** Implement mathematical models to simulate atmospheric conditions and generate weather

forecasts. **Climate Modeling:** Use models to predict long-term climate trends and assess potential impacts of climate change.

iv. **User Interaction and Visualization: Interactive Maps:** Provide users with interactive maps showing current weather conditions and forecast data**. Dashboards**: Develop userfriendly dashboards for meteorologists to monitor weather patterns and forecasts. **Alerts and Notifications:** Send alerts and notifications to users about severe weather conditions, such as storms, heatwaves, or floods.

v. **Data Storage and Management: Database Management**: Store large volumes of weather data efficiently and securely. **Data Retrieval:** Allow users to query and retrieve historical and real-time weather data.

vi. **Reporting and Documentation: Report Generation:** Generate detailed weather reports for various stakeholders, including government agencies, disaster management teams, and the general public. **Documentation:** Maintain comprehensive documentation of system features, usage guidelines, and technical specifications.

3.4.1.2 Non-Functional Attributes of the System

Non-functional attributes refer to the quality characteristics that define how the system performs its functions. These attributes focus on the operational aspects and constraints of the system. For a weather prediction system, non-functional attributes include:

i. **Performance: Scalability**: The system must handle increasing amounts of data and users without degrading performance. **Response Time:** Ensure low latency in data processing and delivering forecasts, particularly for real-time applications. **Reliability, Availability:** The system should be available and operational 24/7 to provide continuous weather monitoring and forecasting. **Fault Tolerance:** Implement mechanisms to ensure the system can recover from failures and continue to operate without significant downtime. ii. **Accuracy: Precision of Predictions:** Ensure the weather models and forecasts are highly accurate, reducing the margin of error in predictions. **Data Integrity**: Maintain the integrity and accuracy of data collected from various sources.

iii. **Usability: User Interface:** Design intuitive and easy-to-navigate interfaces for different types of users, from professional meteorologists to the general public. **Accessibility:** Ensure the system is accessible to users with disabilities, adhering to relevant accessibility standards.

iv. **Security: Data Security**: Protect sensitive weather data from unauthorized access and breaches. **User Authentication:** Implement robust authentication and authorization mechanisms to secure user access.

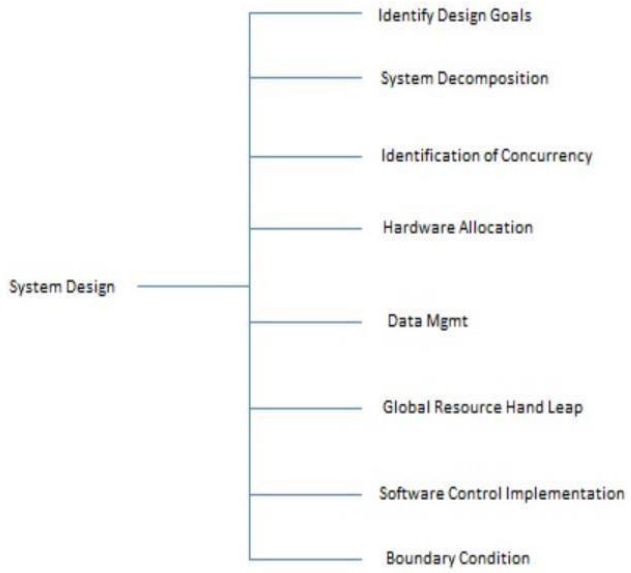
v. **Maintainability: Modularity:** Design the system with modular components to facilitate easy updates, maintenance, and scalability. **Documentation:** Provide thorough documentation to support system maintenance and updates.

vi. **Interoperability: Integration with Other Systems**: Ensure the weather prediction system can seamlessly integrate with other systems, such as emergency management platforms, GIS systems, and data analytics tools. **Standard Compliance:** Adhere to industry standards and protocols for data exchange and system integration.

vii. **Legal and Regulatory Compliance: Compliance:** Ensure the system complies with relevant legal and regulatory requirements, such as data protection laws and environmental regulations.

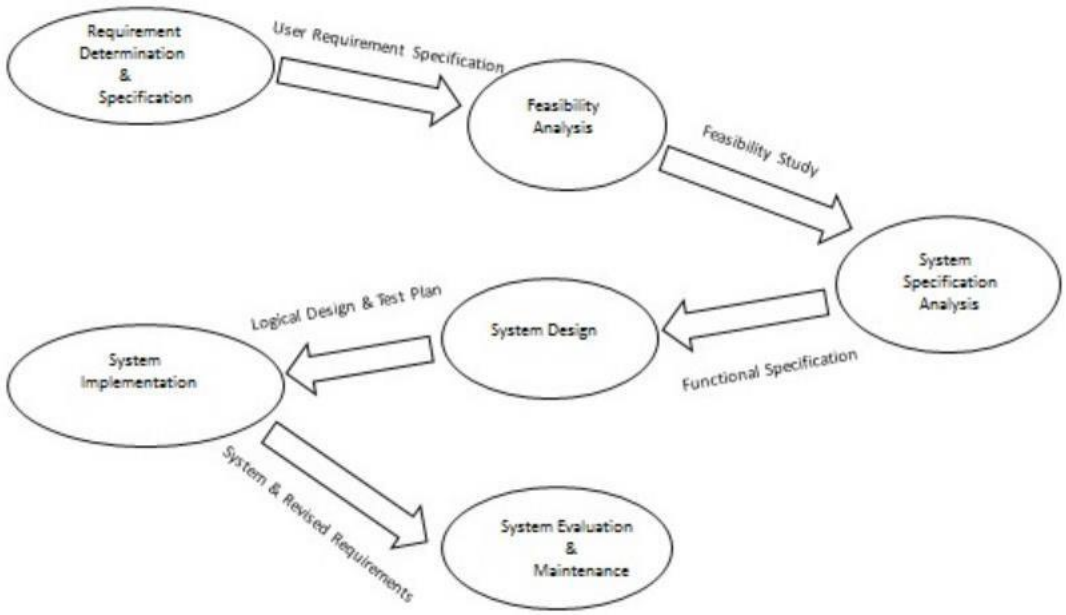
3.4.2 System Design

System design is the phase that bridges the gap between problem domain and the existing system in a manageable way. This phase focuses on the solution domain, i.e. *"how to implement?"* It is the phase where the SRS document is converted into a format that can be implemented and decides how the system will operate. In this phase, the complex activity of system development is divided into several smaller sub-activities, which coordinate with each other to achieve the main objective of system development.



3.4.3 Life Cycle of System Analysis and Design

The following diagram shows the complete life cycle of the system during analysis and design phase.

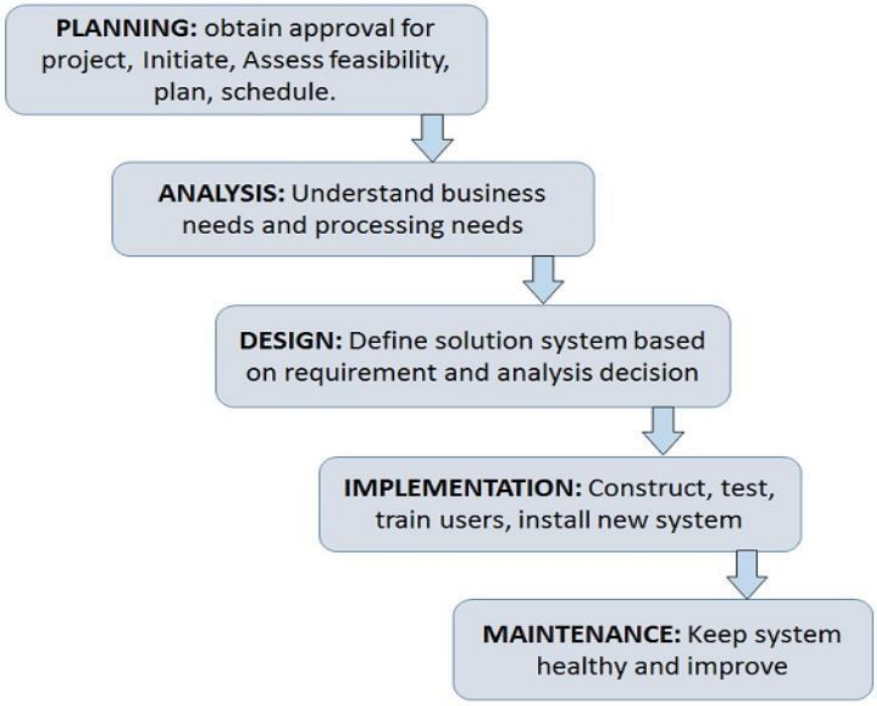


3.5 System Development Life Cycle

An effective System Development Life Cycle (SDLC) should result in a high quality system that meets customer expectations, reaches completion within time and cost evaluations, and works effectively and efficiently in the current and planned Information Technology infrastructure. System Development Life Cycle (SDLC) is a conceptual model which includes policies and procedures for developing or altering systems throughout their life cycles. SDLC is used by analysts to develop an information system. SDLC includes the following activities: requirements, design, implementation, testing, deployment, operations, and maintenance.

3.5.1 Phases of SDLC

Systems Development Life Cycle is a systematic approach which explicitly breaks down the work into phases that are required to implement either new or modified Information System.



3.5.1.1 Feasibility Study or Planning

- Define the problem and scope of existing system.
- Overview the new system and determine its objectives.
- Confirm project feasibility and produce the project Schedule.
- During this phase, threats, constraints, integration and security of system are also considered.
- A feasibility report for the entire project is created at the end of this phase.

3.5.1.2 Analysis and Specification

- Gather, analyze, and validate the information.
- Define the requirements and prototypes for new system.
- Evaluate the alternatives and prioritize the requirements.
- Examine the information needs of end-user and enhances the system goal.
- A Software Requirement Specification (SRS) document, which specifies the software, hardware, functional, and network requirements of the system is prepared at the end of this phase.

3.5.1.3 System Design

- Includes the design of application, network, databases, user interfaces, and system interfaces.

- Transform the SRS document into logical structure, which contains detailed and complete set of specifications that can be implemented in a programming language.
- Create a contingency, training, maintenance, and operation plan.
- Review the proposed design. Ensure that the final design must meet the requirements stated in SRS document.
- Finally, prepare a design document which will be used during next phases.

3.5.1.4 Implementation

- Implement the design into source code through coding.
- Combine all the modules together into training environment that detects errors and defects.
- A test report which contains errors is prepared through test plan that includes test related tasks such as test case generation, testing criteria, and resource allocation for testing.
- Integrate the information system into its environment and install the new system.

3.5.1.5 Maintenance/Support

- Include all the activities such as phone support or physical on-site support for users that is required once the system is installing.
- Implement the changes that software might undergo over a period of time, or implement any new requirements after the software is deployed at the customer location.
- It also includes handling the residual errors and resolve any issues that may exist in the system even after the testing phase.
- Maintenance and support may be needed for a longer time for large systems and for a short time for smaller systems.

3.6 System Implementation

System implementation is the phase where the design of the system is translated into a working application. This involves writing code, configuring hardware and software environments, integrating various components, and conducting thorough testing to ensure the system operates as intended. It is to be achieved using the Data Definition Language (DDL) of the selected Database Management System (DBMS).

3.6.1 Implementation Tools

In the implementation stage, the following tools were used; WAMP/Apache server, MySQL, PHP, VS Code, Python, JavaScript, Windows operating system. (As the development environment).

3.6.1.1 WampServer (WAMP (Windows, Apache, MySQL, PHP) / Apache Server

Windows: Operating system on which WAMP is installed. **Apache:** Web server software that serves web pages to clients. Apache is responsible for handling requests, serving static and dynamic content, and managing web traffic. **MySQL:** Relational database management system (RDBMS) used for storing and retrieving structured data. **PHP:** Server-side scripting language used to create dynamic web pages and interact with the MySQL database. WampServer is a free server bundle that uses Apache server. When installed on the system, it includes Apache, MySQL, and PHP. Apache is a popular web server that many ISPs and individuals use to host web pages. I shall install Apache on my system as a web server. Pages were stored in the system's special folder which was accessible on the network via the machine's IP address. In order for pages to be viewed on the Internet, the files were stored in the www directory.

3.6.1.2 PHP

Hypertext Preprocessor is an open source server side programming language extensively used for web scripts. It is a popular Server-Side Scripting Language, embedded in HTML to create dynamic web pages. It processes on the server and outputs HTML to the client's browser, and is used (often in conjunction with MySQL) in Content Management Systems and other web applications. It is available on many platforms, including Windows, Unix/Linux and Mac OS X, and any open source software. I ought building my content management system using this tool.

3.6.1.3 MySQL

MySQL is an open source Relational Database Management System (RDBMS) that uses Structured Query Language (SQL), the most popular language for adding, accessing, and processing data in a database. Stores data in tables with rows and columns, allowing for efficient data retrieval and manipulation. Because it is open source, anyone can download MySQL and tailor it to their needs in accordance with general public license. MySQL is noted mainly for its speed, reliability, and flexibility. I shall use MySQL because it is designed as a multi-tasking/ multi-user database, which is one of the main requirements for a database.

3.6.1.4 HTML

HTML, referring to Hypertext Markup Language, is the predominant markup language for web pages. It provides a means to describe the structure of text-based information in a document by denoting certain text as links, headings, paragraphs, and lists, among others and to supplement that text with interactive forms, embedded images and other objects. HTML is written in the form of tags, surrounded by angle brackets. HTML can also describe, to some degree, the appearance and

semantics of a document, and include embedded scripting language code which can affect the behavior of Web browsers and other HTML processor. I shall use Visual Studio Code environment to construct both HTML and PHP pages that served on the content management system.

3.6.1.5 Visual Studio Code (VS Code)

Integrated Development Environment (IDE): A powerful, open-source code editor with support for debugging, version control, and extensions. **Coding:** Write, edit, and debug code in multiple programming languages, including PHP, JavaScript, and Python. **Extensions:** Enhance functionality with extensions for lining, formatting, and code snippets. **Version Control Integration:** Integrate with Git for version control, enabling collaboration and tracking changes.

3.6.1.6 JavaScript

Client-Side Scripting Language: Executes in the user's browser, enabling interactive and dynamic web pages. **User Interface Interactivity:** Enhance user experience with interactive elements like maps, charts, and real-time data updates. **AJAX:** Use Asynchronous JavaScript and XML (AJAX) to fetch data from the server without reloading the page, providing a seamless user experience. **Frontend Frameworks:** Utilize frameworks and libraries like React, Angular, or Vue.js to build complex and responsive user interfaces.

3.7 System Testing and Validation

3.7.1 Testing

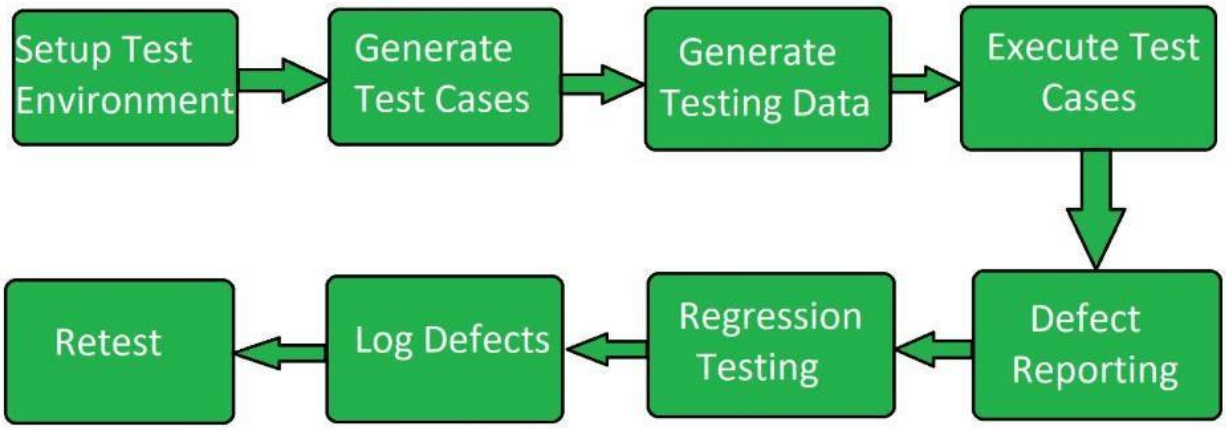
System testing is a type of software testing that evaluates the overall functionality and performance of a complete and fully integrated software solution. It tests if the system meets the specified requirements and if it is suitable for delivery to the end-users. This type of testing is performed after the integration testing and before the acceptance testing.

3.7.1.1 System Testing processes

System testing is performed basing on the following steps:

- Test Environment Setup: Create testing environment for the better quality testing.
- Create Test Case: Generate test case for the testing process.
- Create Test Data: Generate the data that is to be tested.
- Execute Test Case: After the generation of the test case and the test data, test cases are executed.
- Defect Reporting: Defects in the system are detected.
- Regression Testing: It is carried out to test the side effects of the testing process.

- Log Defects: Defects are fixed in this step.
- Retest: If the test is not successful then again test is performed.

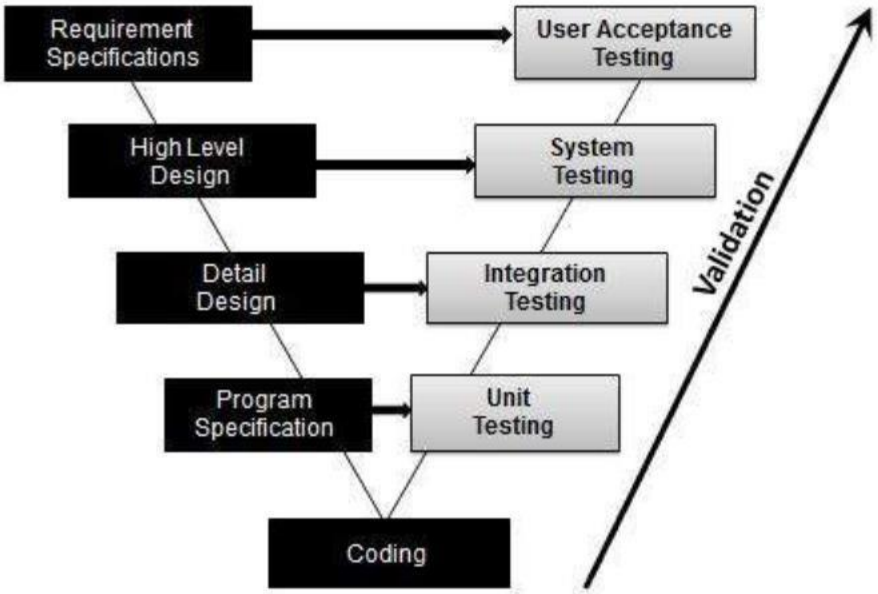


3.7.1.2 Tools used for System Testing

1) JMeter
2) Gallen Framework
3) HP Quality Center/ALM
4) IBM Rational Quality Manager
5) Microsoft Test Manager
6) Selenium
7) Appium
8) LoadRunner
9) Gatling

3.7.2 Validation

Validation is the process of evaluating software during the development process or at the end of the development process to determine whether it satisfies specified business requirements. Validation Testing ensures that the product actually meets the client's needs. It can also be defined as to demonstrate that the product fulfills its intended use when deployed on appropriate environment. Validation shall be done by providing the system to end user representatives who try out the system so as to verify that it meets the intended user requirements. Validation testing can be best demonstrated using V-Model. The Software/product under test is evaluated during this type of testing.



3.7.3 Conclusion

In summary, this chapter described the methodologies that were used for the different patterns of research, approaches to data collection, techniques for analysis and tools that are used for designing and implementation of the system.

Chapter Four

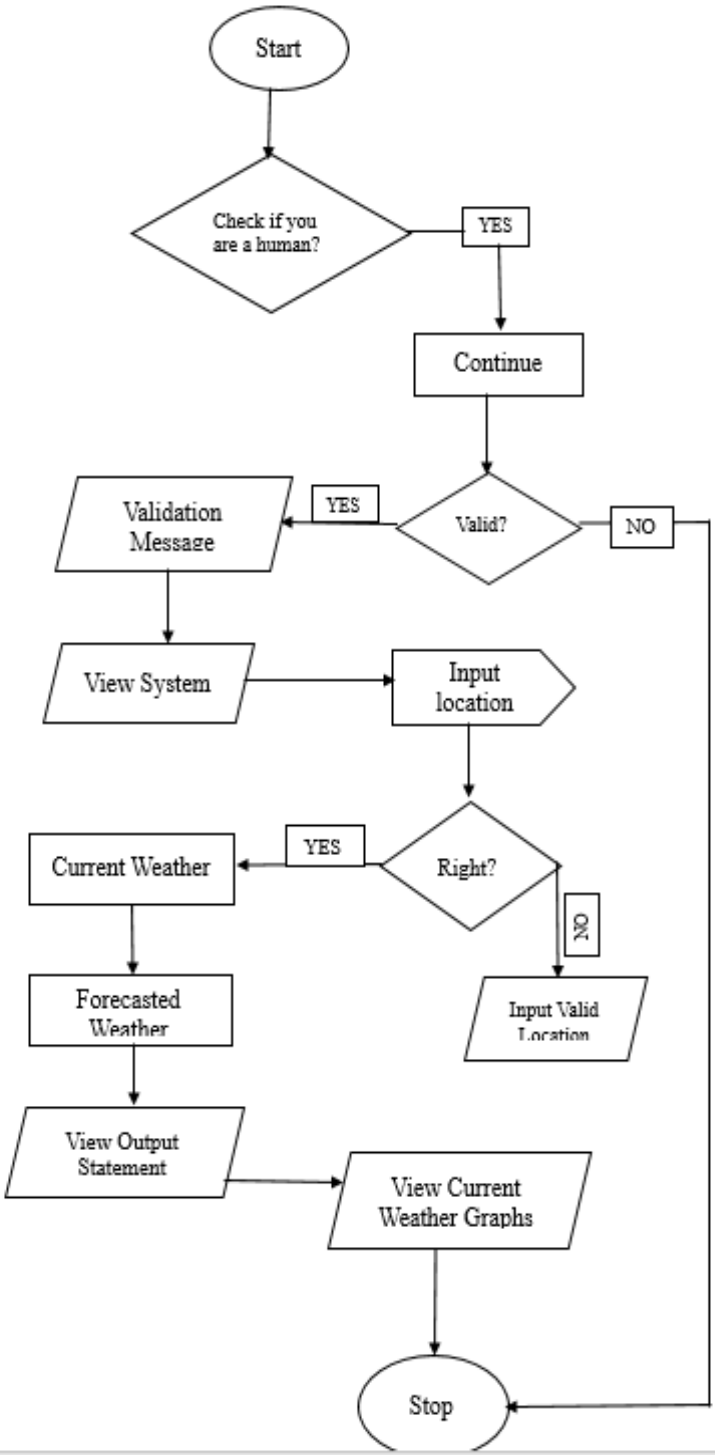
4.0 System Study, Analysis and Design

This chapter concerns the study of the existing system, analysis of the requirements for the system, process and data modeling.

4.1 The study of the Existing System

From the data gathered about the existing Weather Forecasting Systems through interviews, observation and review of existing documents (documentation review), I found out that the study of existing weather forecasting systems reveals several critical areas for enhancement tailored to the specific needs of Bududa District. Current systems often fall short in accurately predicting microclimates, an essential factor given Bududa's diverse topography. These systems typically rely on broad-scale data, which may not adequately capture the unique weather patterns influenced by the region's terrain. Moreover, the integration of local weather stations and community-reported data is limited, resulting in less precise forecasts. User accessibility also poses a challenge; many existing platforms are not user-friendly for local farmers, who require straightforward, actionable information to make informed decisions. By addressing these gaps, the development of a new Weather Prediction System can provide more accurate, localized, and user-centric forecasts, ultimately supporting the agricultural community and enhancing disaster preparedness in Bududa District. (See Figure 4.1).

4.1.1 Workflow for Weather Prediction System Processes



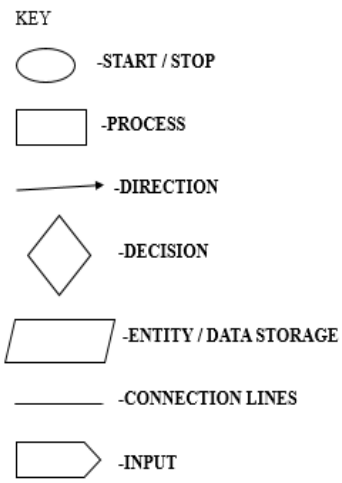


Figure 4. 1: Flow chart for the Weather Prediction System

4.1.2 Strength of the existing system

A. Mega Phones Devices

The benefits or strength of Mega Phones Devices are;

i. Hyperlocal Forecasting: Minute-by-Minute Predictions, Mega Phones Devices provides extremely localized forecasts, giving minute-by-minute updates for the next hour.

ii. User-Friendly Interface: Intuitive Design: The app features a clean, easy-to-navigate interface that makes it simple for users to find the information they need quickly.

iii. Real-Time Notifications: Timely Alerts, Users receive real-time notifications about weather changes and severe weather alerts, helping them stay prepared.

iv. Integration and Accessibility: Cross-Platform Availability, Mega Phones Devices is available on multiple platforms, including iOS, Android, and web, ensuring accessibility across different devices.

v. Detailed Weather Data: Comprehensive Information, Users have access to detailed weather data, including temperature, precipitation, wind speed, humidity, and UV index.

vi. Reliable and Up-to-Date: Continuous Updates, Mega Phones Devices continuously updates its data, ensuring that users receive the most current and accurate weather information.

B. Weather Station at the District Quarters

The benefits or strengths of Weather Station are;

i. **Localized Data Collection**: Weather stations in Bududa can provide highly localized weather data, which is crucial for accurate weather predictions and monitoring in the region.
ii. **Real-time Monitoring**: Real-time data collection allows for immediate analysis and response, which is essential in regions prone to sudden weather changes, like Bududa, which is susceptible to landslides and heavy rainfall.
iii. **Support for Agricultural Activities**: Farmers can benefit from precise weather data to make informed decisions regarding planting, irrigation, and harvesting, reducing crop losses due to unexpected weather events.
iv. **Disaster Preparedness and Management**: Accurate weather monitoring can improve early warning systems for natural disasters like landslides, helping to mitigate the impact on lives and property.
v. **Data for Research and Policy Making**: Weather stations provide essential data that can be used for research and to inform policies aimed at environmental conservation and disaster risk reduction in Bududa.

4.1.3 Weakness of the existing System

A. Mega Phones Devices

The weaknesses of Mega Phones Devices are;

i. Accuracy in Certain Locations: Limited Data Sources, in areas with fewer weather stations or less comprehensive data sources, the accuracy of Mega Phones Devices forecasts can be reduced. Dependence on Crowdsourcing, while crowdsourced data can enhance accuracy, it can also introduce variability and inconsistencies.
ii. User Interface Issues: Complexity for Some Users, while many users appreciate the detailed visualizations, some find the interface to be overly complex or not intuitive enough, particularly those who prefer a more straightforward weather app.
iii. Battery and Data Usage: High Resource Consumption, the app's use of real-time data updates,
GPS, and dynamic visualizations can lead to higher battery consumption and increased data usage
iv. Subscription Model: Cost, Mega Phones Devices operates on a subscription model for some of its features, which can be a drawback for users who are looking for a free weather app.
v. Privacy Concerns: Data Collection, some users have expressed concerns about the amount of location data and personal information collected by the app.

vi. Limited Customization: Inflexible Settings, some users have found that the app does not offer as much customization as they would like. vii. Competitor Advantages: Strong Competition, there are many other weather apps available that offer similar or additional features.

B. Weather Station for Bududa district

The weaknesses or problems of Weather Station for Bududa district are;

i. High Maintenance Costs: Weather stations require regular maintenance and calibration to function accurately, which can be costly and challenging, especially in remote areas like Bududa.
ii. Limited Coverage: A single weather station may not provide sufficient coverage for the entire district, leading to gaps in data collection, especially in areas with varied topography.
iii. Vulnerability to Environmental Factors: Weather stations can be affected by extreme weather conditions, such as heavy rains, floods, or landslides, which may damage the equipment and disrupt data collection.
iv. Dependence on Power and Connectivity: Continuous operation of weather stations requires reliable power and internet connectivity, which might be unreliable in rural areas like Bududa.
v. Initial Setup Costs: The cost of purchasing and installing weather stations can be prohibitive, especially for comprehensive coverage across the district.
vi. Technical Expertise Required: Operating and interpreting data from weather stations requires technical expertise, which may not always be readily available locally.

4.2.1 The Tabular representation of the Challenges associated with the current Weather Systems

Challenges	Number of Respondents	Percentage
Inadequate data on current weather and forecasts	4	60
Unclear communication and interpretation	2	70
Rapidly Changing weather	4	40

patterns		
Limited Public awareness and education	3	80
Modeling complexities	4	55

4.2.2 The Graphical representation of the challenges faced by the current Weather Systems

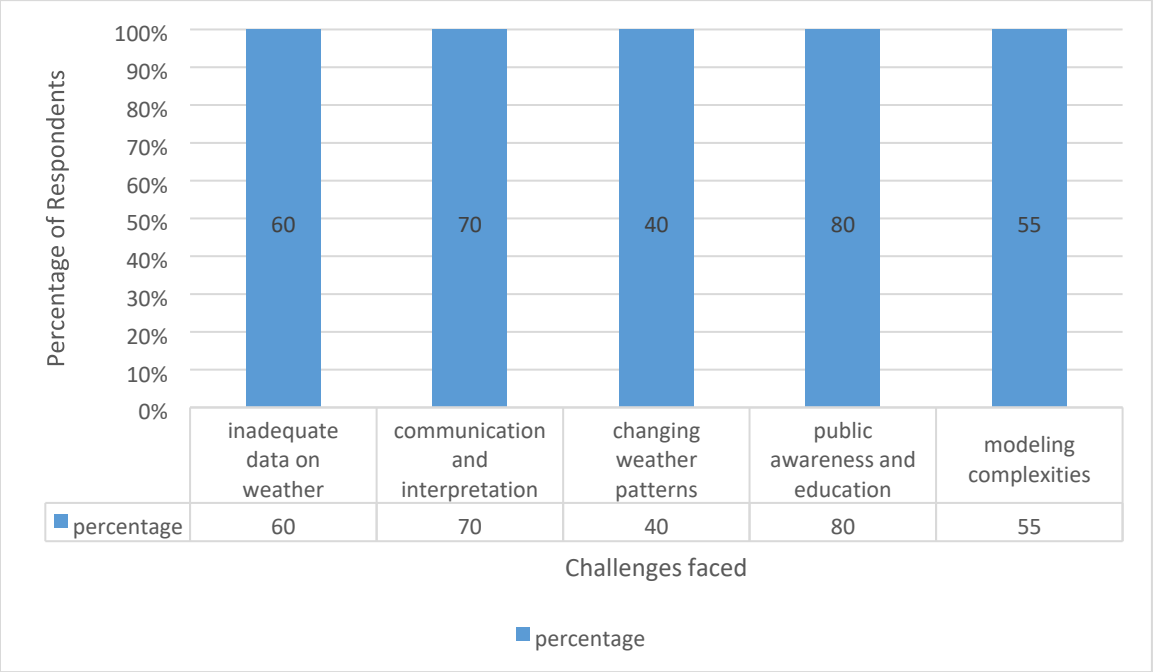


Figure 4. 2: A graphical presentation of the challenges faced by the current weather system.

4.3 User Requirements

These are statements, in a natural language, of what services the system is expected to provide and the constraints under which it must operate. Below are the user requirements for the system;

i. The system should generate current weather data. Display real-time temperature, humidity, wind speed, pressure and show sunrise and sunset times
ii. The system should include a graphical representation of line and bar graphs for current weather data of temperature and humidity respectively. iii. The system should show 5-Day Forecast.

Display forecast data (every 3 hours) for temperature, humidity, wind speed, cloudiness and pressure

iv. The system should store data; current weather and 5-Day forecast with timestamp and location information.

v. The system should have a user friendly interface designed for accessing current weather and forecasts

vi. The system should provide user notifications to show alerts and notifications about significant weather changes and warnings.

vii. The system should be assessable to also the users with disabilities, adhering to relevant accessibility standards

viii. The system should be secure, implementing measures to protect user data and ensure secure data transactions.

4.3.1 Functional requirements

A Functional requirement are the specific behaviors, tasks, and functions that the system must perform to meet the needs of its users, as per this its regards to the weather perspective. These requirements describe how the system should operate, what data it should process, and how it should interact with users and external systems;

i. The system should do data retrieval. Fetch real time weather data, the system must retrieve the current weather conditions and fetch 5-Day forecast data for the next five days, with details available at 3-hour intervals.

ii. The system should display data. The system must present real time current weather data on the user interface with location specific details, and too display 5-Day Forecast respectively. iii. The system should enable data storage. The system must store real time current weather data and 5-Day Forecast in the database with same attributes of time, date, location and weather parameters.

iv. The system should do Data integration. The system integrates with external weather APIs to continuously fetch up-to-date data weather information and thus does automated Data Updates.

v. The system should have a high performance. The system must handle multiple concurrent users and large volumes of data efficiently without noticeable delays and downtime

vi. The system should be highly available, that's to say 24/7, ensuring users to access weather data at any time.

4.3.2 Non-functional requirements

A non-functional requirement is refers to the quality attributes performance standards, and constraints that the system must adhere to. This is unlike the functional requirements that describe what the system should do, Non Functional requirements specify how the system should perform its functions. These include:

i. The system should authenticate users through a robust authentication "Check if you are a Human." This contents the system that user diving to it is not a robot rather a human.
ii. The system should have a high performance in that it provides weather data responses within 2 seconds.
iii. The system should be flexible, and easy to update.
iv. The system should put into consideration usability. The system must have an intuitive and user friendly interface, allowing users to easily navigate and access weather data with minimal training and instruction.
v. The system should be compatible. There must be cross-platform support where the system is compatible with the major web browsers like chrome, firefox and Safari, operating systems like windows, macos and linux
vi. The Weather Prediction System should be reliable in that its 99.9% available ensuring accessibility at any time with minimal down time.

4.3.3 System requirement

The system requirement includes requirements that are needed to include certain functionality in the system. It involved describing the system and the properties in that system. They include the hardware and software requirements as follows;

4.3.3.1 Hardware Requirements

Table 1: Hardware requirements

Hardware component	**System requirement**	**Justification**

Processor	Intel Core i3 or above	Intel Core i3 has the new technology (Hyper Threading) and the number of pins as well as cache memory has been increased. This enables each core to handle 2 threads simultaneously thus improving multithreading performance.
Processor speed	2.20GHZ or above	This has enough speed, to run and fetch requests the Weather Prediction System.
Disk space	100 GB or above	This is enough disk space or storage size for the data storage in the database of the Weather Prediction System.

4.3.3.2 Software Requirements

Table 2: Software requirements

Software Component	**System Requirement**	**Justification**
Operating System for the server	Windows NT or above	Windows NT adopts a new layered device-driver architecture that provides many advantages in terms of flexibility, maintainability, and portability.
Operating system for the client PC	Windows XP	Windows XP can be used on personal computers, including home and business desktops, laptops and media centres.
Web Server	Apache Web Server Version 1.3	This is a web server software notable for playing a key role in the initial growth of the World Wide Web.
Web Browser	Opera Mobile Emulator	It is the default browser shipped with Windows XP and is also made available for Windows NT 4.0.
Database Management System	MySQL server version 3:23.48	MySQL is an open source relational database management system (RDBMS) that runs as a server providing multi-user access to a number of databases.

Visual Studio (VS) Code	Windows 8 or above 64bit OS Internet Connection	VS Code is built using modern technologies and requires a 64bit Operating System to run efficiently. The internet connection is necessary for downloading extensions, updates, and other resources that enhance VS experience

4.3 System Design

System design is the process of defining the architecture, components, and infrastructure of a system to meet specific requirements and needs. In the system design phase, process modeling involved use of Data Flow Diagrams (DFD), and Data modeling involved use of Entity Relationship Diagrams (ERD).

4.3.1 Architectural Design for the System

The architectural design shows how the Weather Prediction System is comprised of the different subsystems namely Data collection, Data Processing, Data Storage and Data Display. The figure below shows an architectural diagram of the Weather Prediction System.

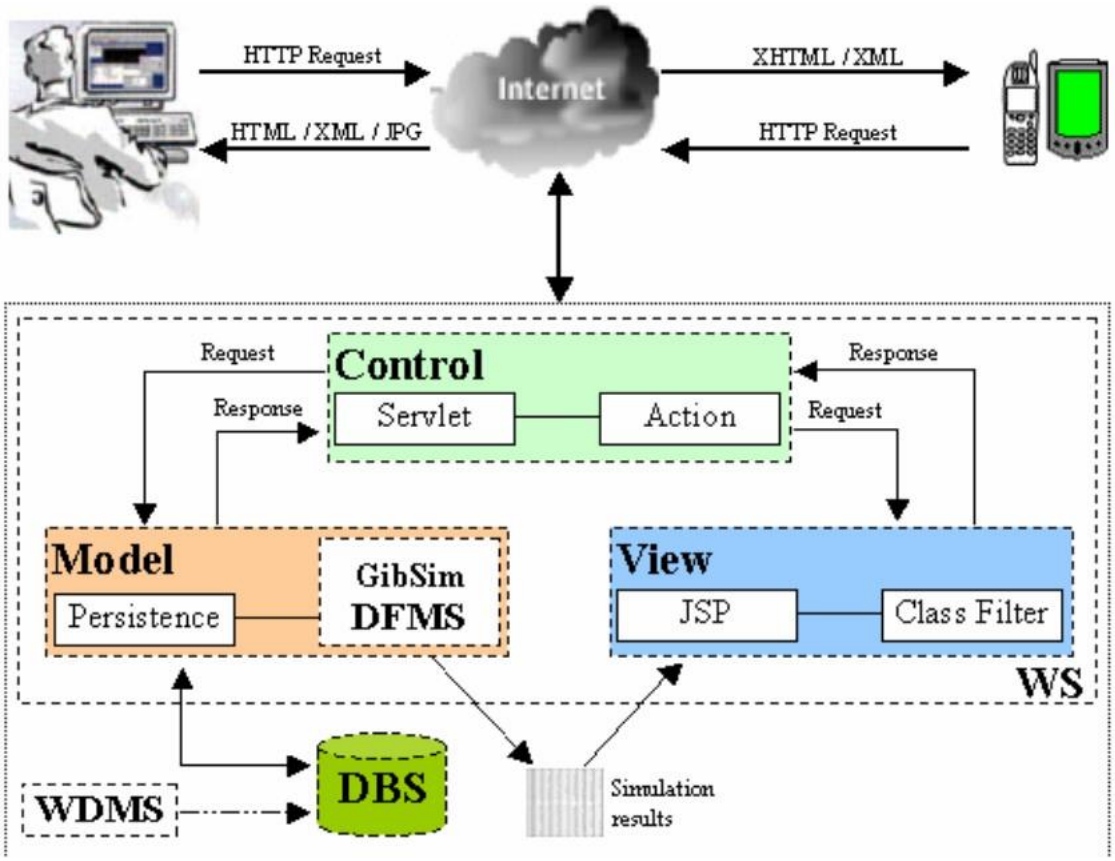
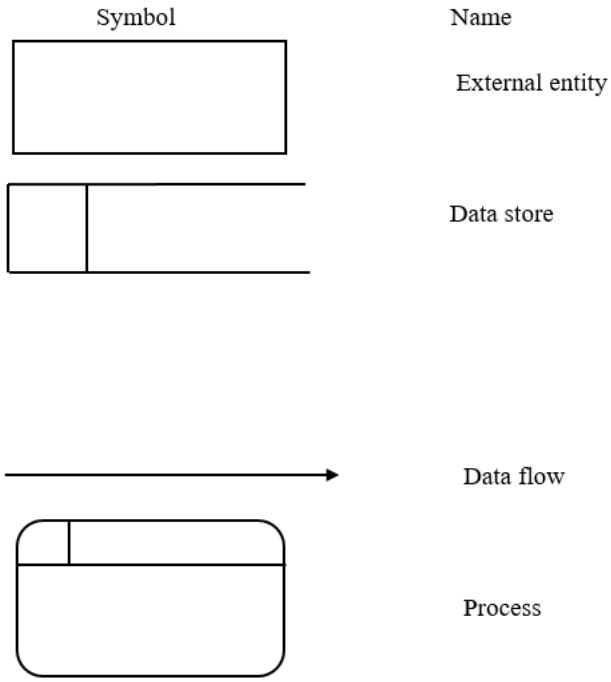


Figure 4. 3: The Architectural Design for weather prediction system

4.3.2 Process Modeling

These show how information or data will be moving around the financial Management System from the entry to various repositories or data stores.

4.3.2.1 Key Symbols



Description of the above key symbols;

i. An Entity is a real life object with an independent existence that interacts with the system. ii. Data store shows where data is stored after being processed. This can be a database or a file.
iii. Data flow shows the movement of data within the system and also connects processes, data stores and external entities.
iv. A Process is a series of activities or actions to accomplish a desired task.

4.3.3 Data Flow Diagrams (DFD).

These are diagrams used to graphically represent the flow of data in a business information system. DFD describes the processes that are involved in a system to transfer data from the input to the file storage and reports generation. Data flow diagrams can be divided into logical and physical. It is one of the most important modeling tools used by system analysts. It is used to illustrate how data flows in a system. DFD's use a number of symbols to represent systems. There are four kinds of symbols. These are used to represent four kinds of system components. Processes, data stores, data flows and external entities.

Illustration

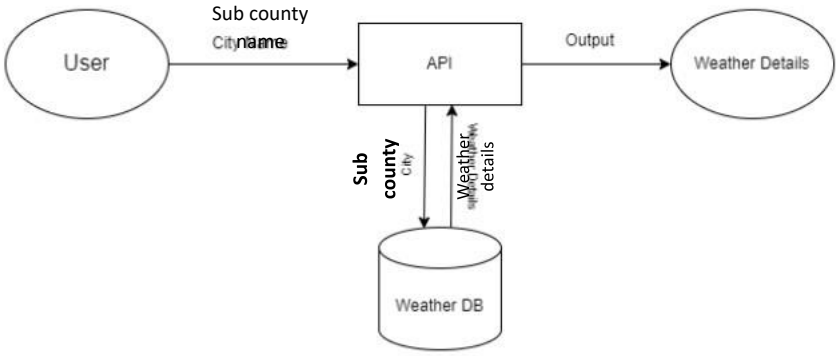


Figure 4. 4: The Data flow Diagram for weather prediction system

4.3.3.1 The Context Level DFD

Level 0 DFDs, also known as context diagrams, are the most basic data flow diagrams. They provide a broad view that is easily digestible but offers little detail. Level 0 data flow diagrams show a single process node and its connections to external entities. **Illustration**

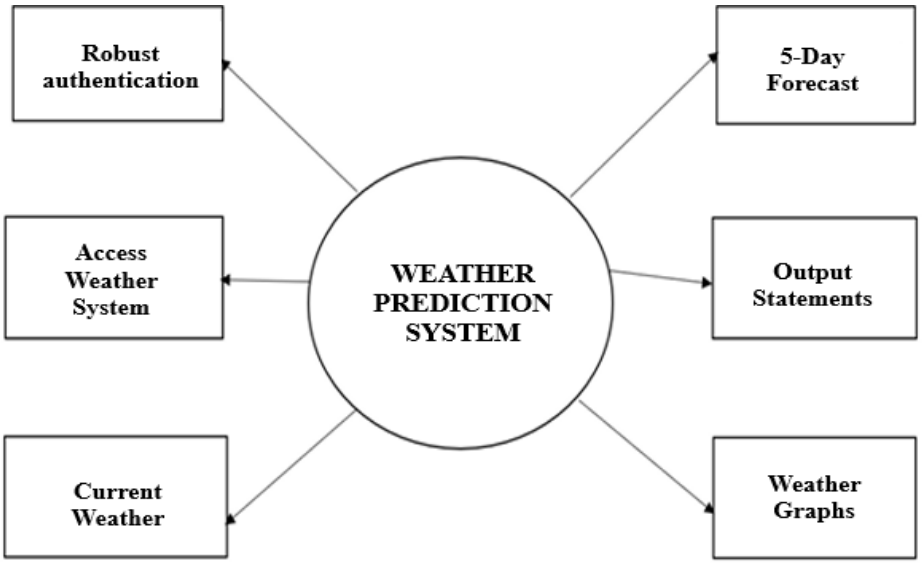


Figure 4. 5: Context Diagram for the Weather Prediction System.

4.3.3.2 The Level 1 DFD for the Weather Prediction System

Level 1 DFDs are still a general overview, but they go into more detail than a context diagram. In level 1 DFD, the single process node from the context diagram is broken down into sub-processes.

As these processes are added, the diagram will need additional data flows and data stores to link them together

Illustration

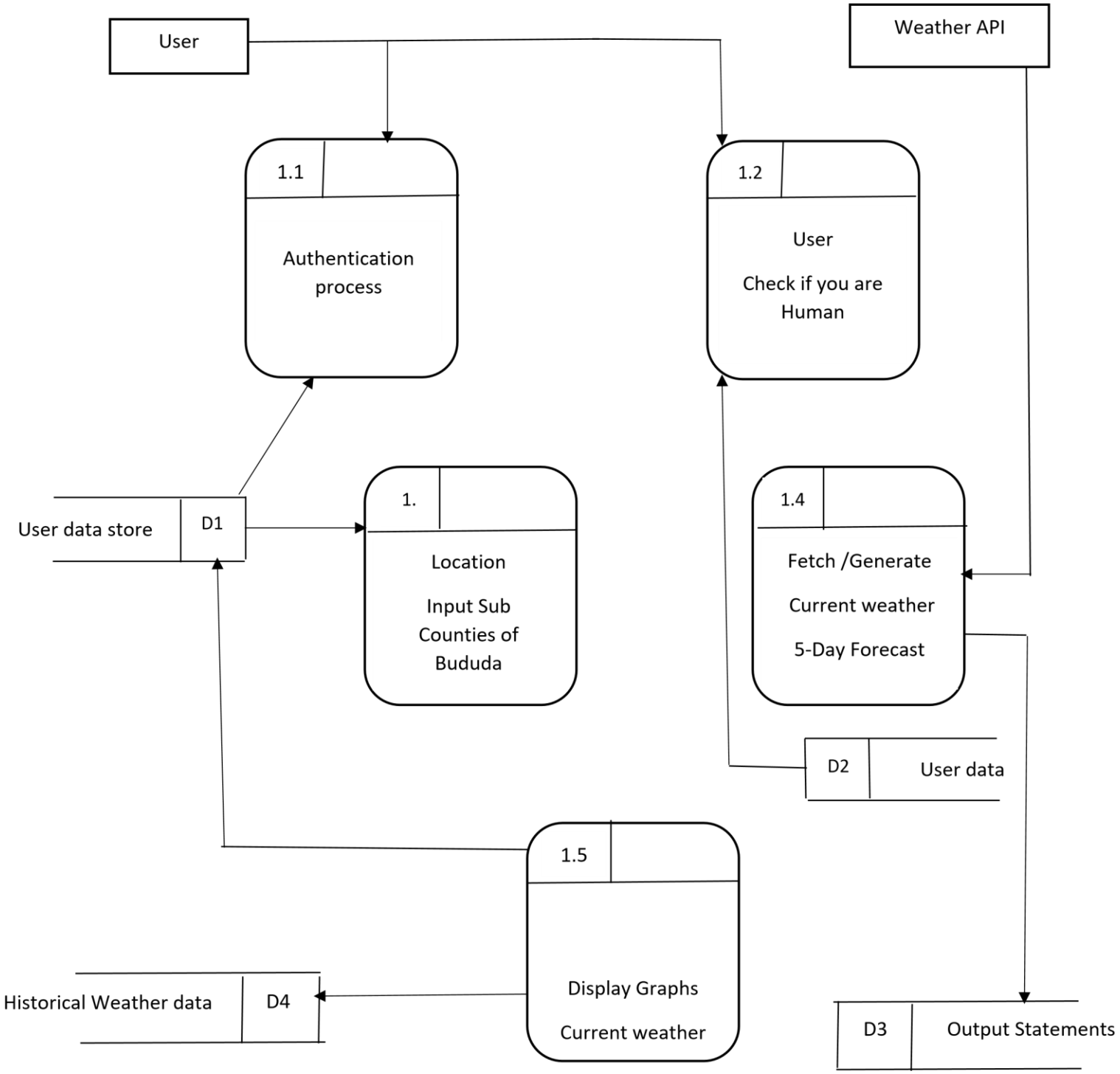


Figure 4. 6: Level 1 DFD for the Weather Prediction System

Description for the level 1 DFD

In this subsection, there are tables describing all the design objects used in developing the system. They include Processes, Data flows, Data stores and the External entities.

Description for Processes

Table 3: Description of Processes

Process	Description
Authentication Process	Prepares to verify if you are a human or robot
User check if Human Process	Check if the user is a Human
Weather Data Fetch Process	Fetches weather data for the openweathermap
Weather Display Process	Shows to the users the changing weather patterns
Data Graph Charts Process	Draws analysis and interpretation of the weather data

Description of Data Stores

Table 4: Description for Data stores

Data store	Description
User Data	Inputs or sends requests to the system
User Data Store	Stores all weather data details
Output Statements	Sends a message to the users as per the weather data

Description for External Entities

Table 5: Description of External Entities

Entity	Description
Weather API	Provides accurate weather data to the system if called
User	Performs a Robust Authentication

4.3.4 Identification of Entities and their Attributes

Table 6: Identification for Entities and their Attributes

Entity	**Description**	**Attributes**
Current Weather	Represents predictions of current weather real time data conditions based on models and historical data.	Current ID Current Date Location Temperature Humidity Wind speed Cloudiness Pressure Sunrise Sun set
Weather Forecast (5-Day Forecast)	Represents predictions of future weather conditions based on models and historical data.	Forecast ID Forecast date Location Temperature Humidity Wind speed
		Cloudiness Pressure

output statements	Represents notifications about severe or extreme weather conditions that could impact safety or operations.	ID Affected Area Effective Date Description

4.3.5 Modeling Relationships between Entities

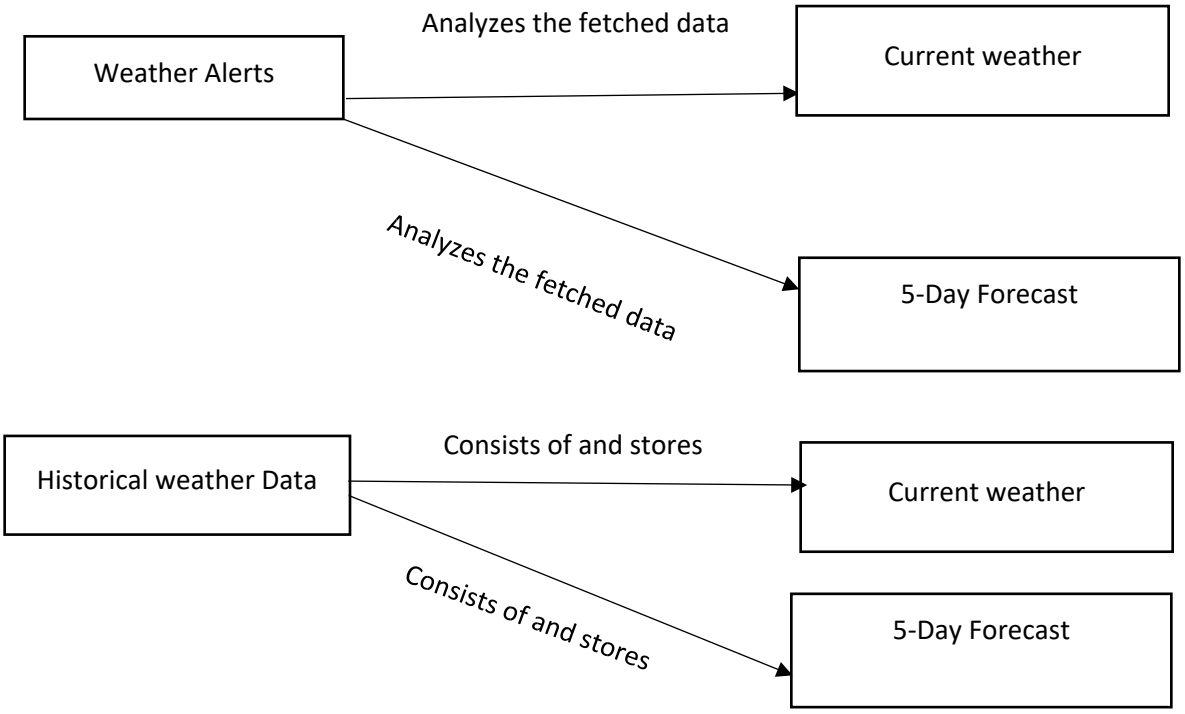


Figure 4. 7: Relationship between Bank and Employee

4.3.6 The Entity Relationship Diagram

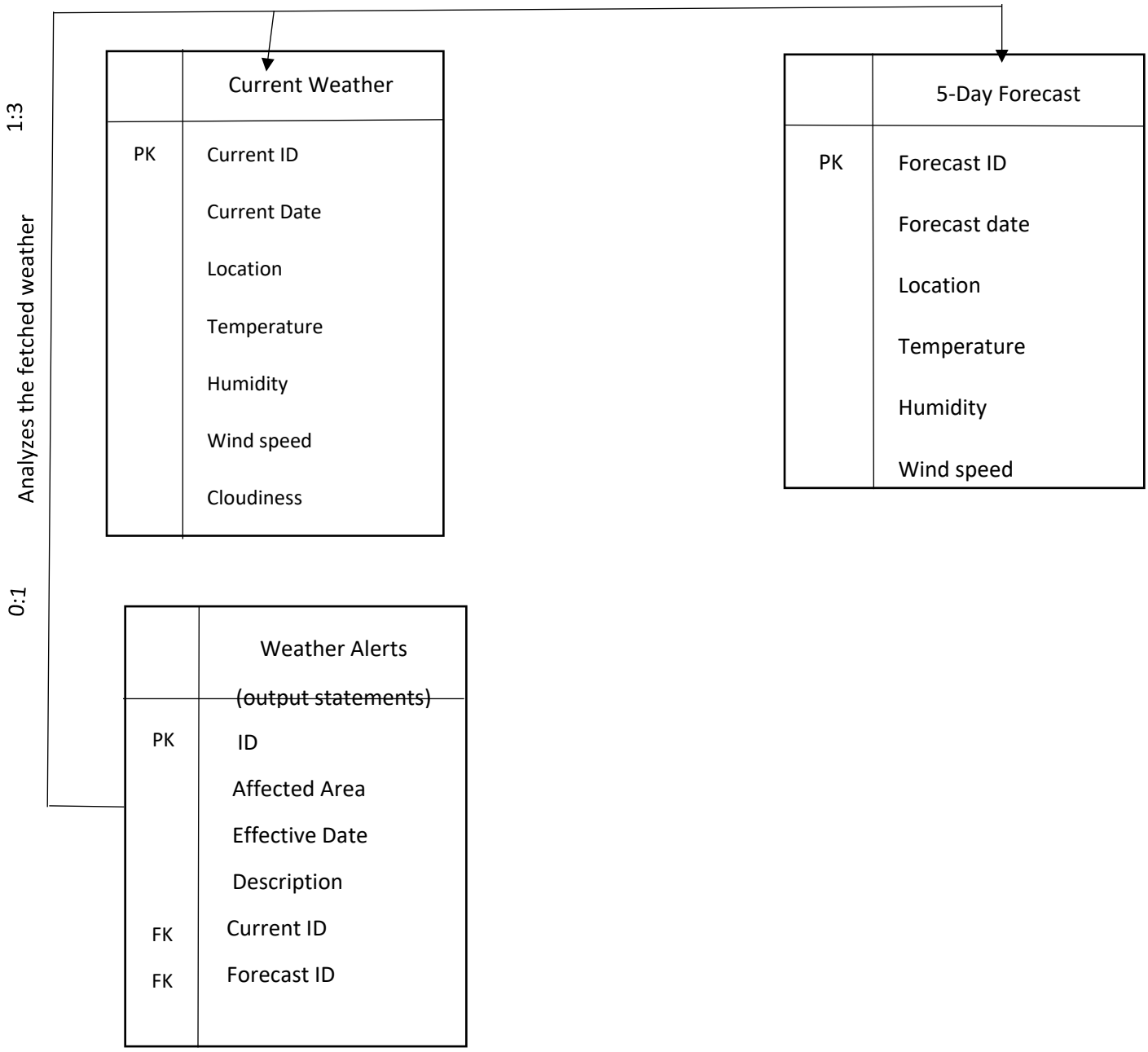


Figure 4. 8: The Entity Relationship Diagram for Weather Prediction system

4.3.7 Mapping of ERD to Relational Schema

4.3.7.1 Current weather

Table 7: The Current Weather

Field Name	Data Type	Constraint
Current ID	int	Primary Key, Not null
Current Date	data	Not null
Location	varchar(20)	Not null
Temperature	float	Not null
Humidity	float	Not null
Wind speed	float	Not null
Cloudiness	int	Not null
Pressure	float	Not null
Sunrise	datetime	Not null
Sun set	datetime	Not null

4.3.7.2 Weather Forecast (5-Day Forecast)

Table 8: The weather forecast

Field Name	Data type	Constraint
Forecast ID	Int	Primary Key, Not null
Forecast date	Date	Not null
Location	varchar(20)	Not null
Temperature	float	Not null
Humidity	float	Not null
Wind speed	float	Not null
Cloudiness	int	Not null
Pressure	float	Not null

4.3.7.3 Output Statements

Table 9: The weather alerts

Field Name	Data Type	Constraint
ID	Int	Primary Key, Not null
Affected Area	Varchar(20)	Not null

Effective Date	date	Not null
Output statement	text	Not null
Current ID	int	Foreign Key, Not null
Forecast ID	int	Foreign Key, Not null

4.4 Conclusion

In summary, this chapter was mainly based on the study of the existing system, analysis of the requirements for the system, processes and data modeling.

Chapter five

5.0 System Implementation, Testing and Validation

This section describes the implementation of the design models in of the system and also shows the different results generated by the system. Therefore screen shots of the system will be displayed to show how the system displays results given a command.

System Implementation is the process of putting a designed system into operation. It involves translating the design into an executable system, integrating different components, and ensuring that the system meets the desired requirements.

Testing is the process of executing the system to identify any errors, gaps, or missing requirements compared to the actual desired outcomes.

Validation ensures that the system meets the needs of its users and that it operates correctly in the real-world environment.

5.1 System Functions

The weather prediction system comprises several key functions that collectively ensure accurate data collection, processing, forecasting, and user interaction. Below is a detailed overview of these system functions:

5.1.1 Data Collection

Real-Time Data Acquisition: Fetch real-time weather data from various sources such as weather stations, satellites, or third-party APIs (e.g., OpenWeatherMap, NOAA).

Collect meteorological parameters such as temperature, humidity, wind speed, wind direction, pressure, precipitation, and cloud cover.

Historical Data Retrieval: Retrieve and store historical weather data for trend analysis and model training. Access and integrate data from external archives or databases to enrich the system's dataset.

Sensor Data Integration: Collect data from on-site sensors or IoT devices deployed in specific locations (e.g., farms, cities) for localized weather monitoring.

5.1.2 Data Processing

Data Cleaning and Normalization: Clean the collected data to remove noise, errors, or inconsistencies. Normalize the data to a standard format, ensuring consistency across different sources and time intervals.

Data Aggregation: Aggregate data from multiple sources to create a comprehensive dataset for analysis. Summarize data over different time intervals (e.g., hourly, daily) as needed for forecasting.

Data Storage: Store raw, processed, and historical weather data in a structured database. Ensure efficient storage and retrieval mechanisms for large datasets.

5.1.3 Weather Forecasting / prediction

Short-Term Forecasting: Generate short-term weather forecasts (e.g., hourly or daily) using realtime data and statistical or machine learning models. Predict key parameters like temperature, humidity, precipitation, and wind conditions.

Long-Term Forecasting: Produce long-term weather forecasts (e.g., weekly or monthly) using historical data and advanced forecasting models. Incorporate seasonal trends and long-term climate patterns into the predictions.

Model Training and Optimization: Train predictive models using historical data and validate them using current data. Continuously optimize models to improve forecasting accuracy over time.

5.1.4 User Interaction

User Interface (UI): Provide a user-friendly interface (web or mobile) where users can access current weather conditions, forecasts, and alerts. Allow users to input their location to receive localized weather information.

Customizable Notifications: Enable users to set preferences for receiving weather alerts and notifications via email, SMS, or app notifications. Allow customization of alert types (e.g., severe weather alerts, daily forecasts).

Interactive Maps and Visualizations: Display interactive weather maps showing temperature, precipitation, and other weather parameters. Provide graphical representations of forecast data (e.g., charts, graphs) for easy interpretation.

5.1.5 Alerting and Notifications

Severe Weather Alerts: Automatically detect severe weather conditions (e.g., storms, floods) and send real-time alerts to users. Include safety instructions or recommendations within the alerts.

Forecast / predict Notifications: Send periodic updates to users with the latest weather forecasts, tailored to their preferences. Provide reminders for specific weather-related events (e.g., frost warnings, heatwaves).

5.1.6 Data Analysis and Reporting

Trend Analysis: Analyze historical and real-time data to identify weather trends and patterns. Generate reports on climate changes, seasonal variations, and extreme weather events.

Custom Reports: Allow users to generate custom reports based on specific weather parameters and time periods. Provide insights into weather patterns for specific industries (e.g., agriculture, aviation).

5.1.7 System Administration

User Management: Manage user accounts, roles, and permissions within the system. Ensure secure access to the system and its data.

System Monitoring: Monitor system performance, including data flow, processing times, and system uptime. Implement automated alerts for system anomalies or failures.

Data Backup and Recovery: Regularly back up weather data and system configurations. Implement disaster recovery plans to restore the system in case of data loss or hardware failure.

5.1.8 Security and Compliance

Data Security: Ensure secure data transmission and storage, using encryption and secure protocols. Protect user data and maintain compliance with data protection regulations (e.g., GDPR).

Access Control: Implement access control mechanisms to ensure that only authorized users can access sensitive data or system functions.

Audit and Logging: Maintain logs of system activity for auditing and compliance purposes. Track changes to data and system configurations for transparency and accountability.

5.2 System map

Figure 5.1: System Map showing functions provided by the system to each user

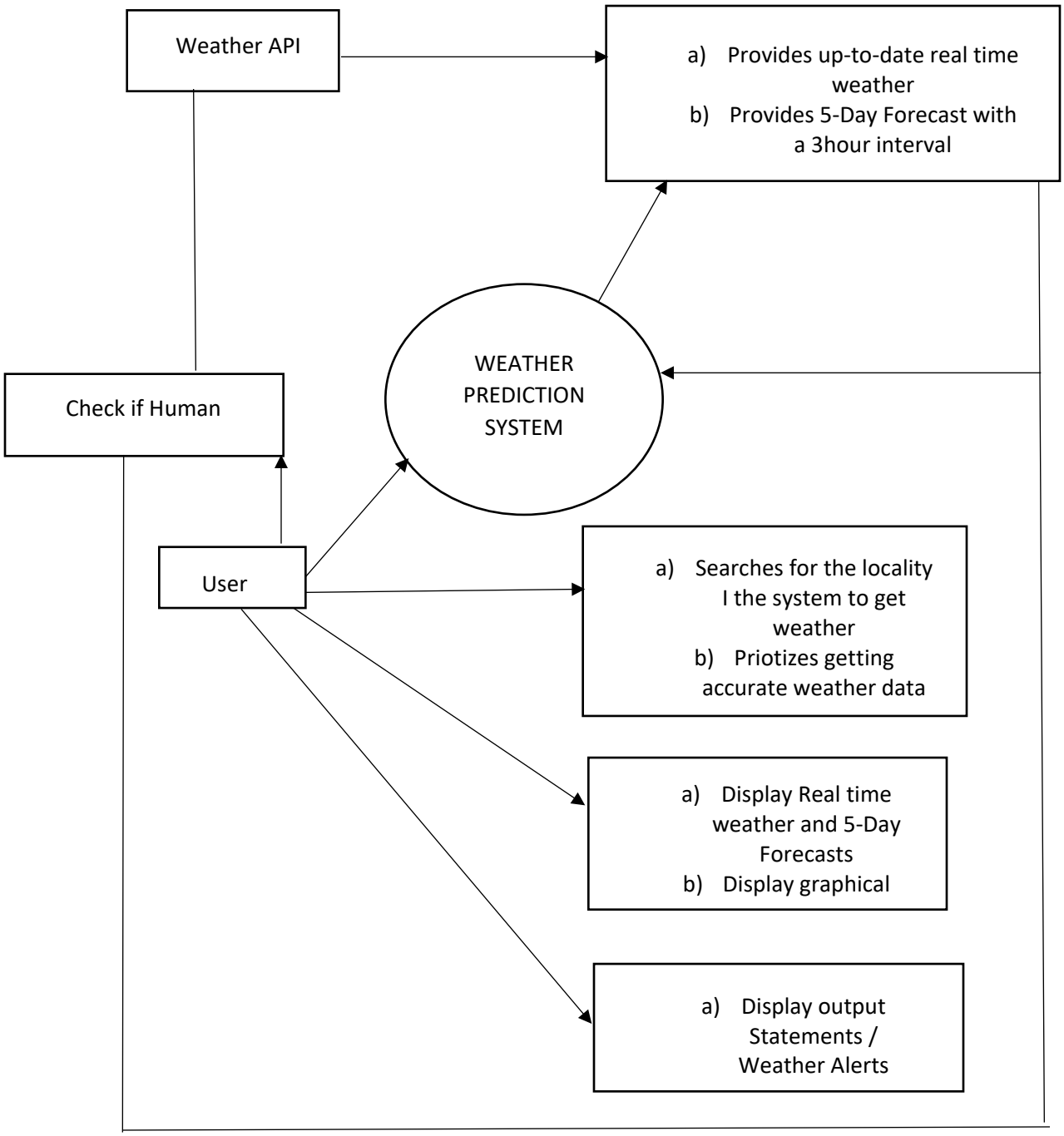


Figure 5. 1: System Map

5.3 Sample Screen-shots

5.3.1 System robust authentication page

Figure 5.2 Shows the robust authentication page that allows all users to verify and confirm they are human not robots in order to access the Weather Prediction system and perform their tasks. On with robust authentication page, the check if human option is accomplished by all users that access

the system, robust authentication page for the users will be displayed as shown on the screenshot below.

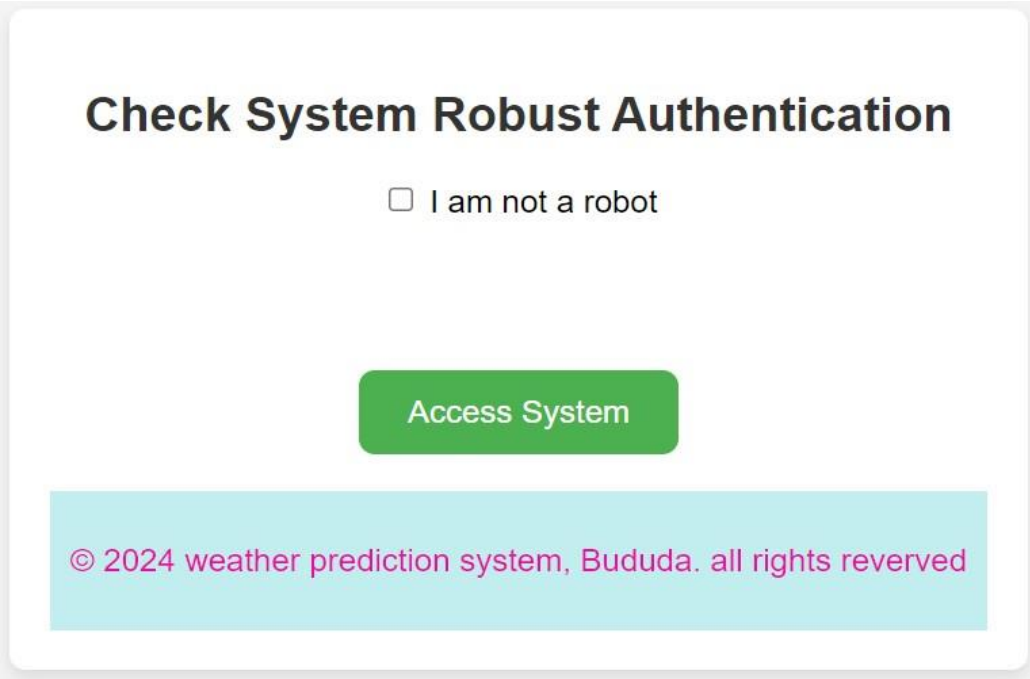


Figure 5. 2: System robust authentication page

5.3.2 System home page

Figure 5.3: Shows the system home page where the user option fills and searches for a locality or sub county of his or her interest in Bududa District. This gives accurate real time / current weather data and 5Day forecast at a 3hour intervals. Also in case of wrong sub county in the search engine, it displays an invalid entry.

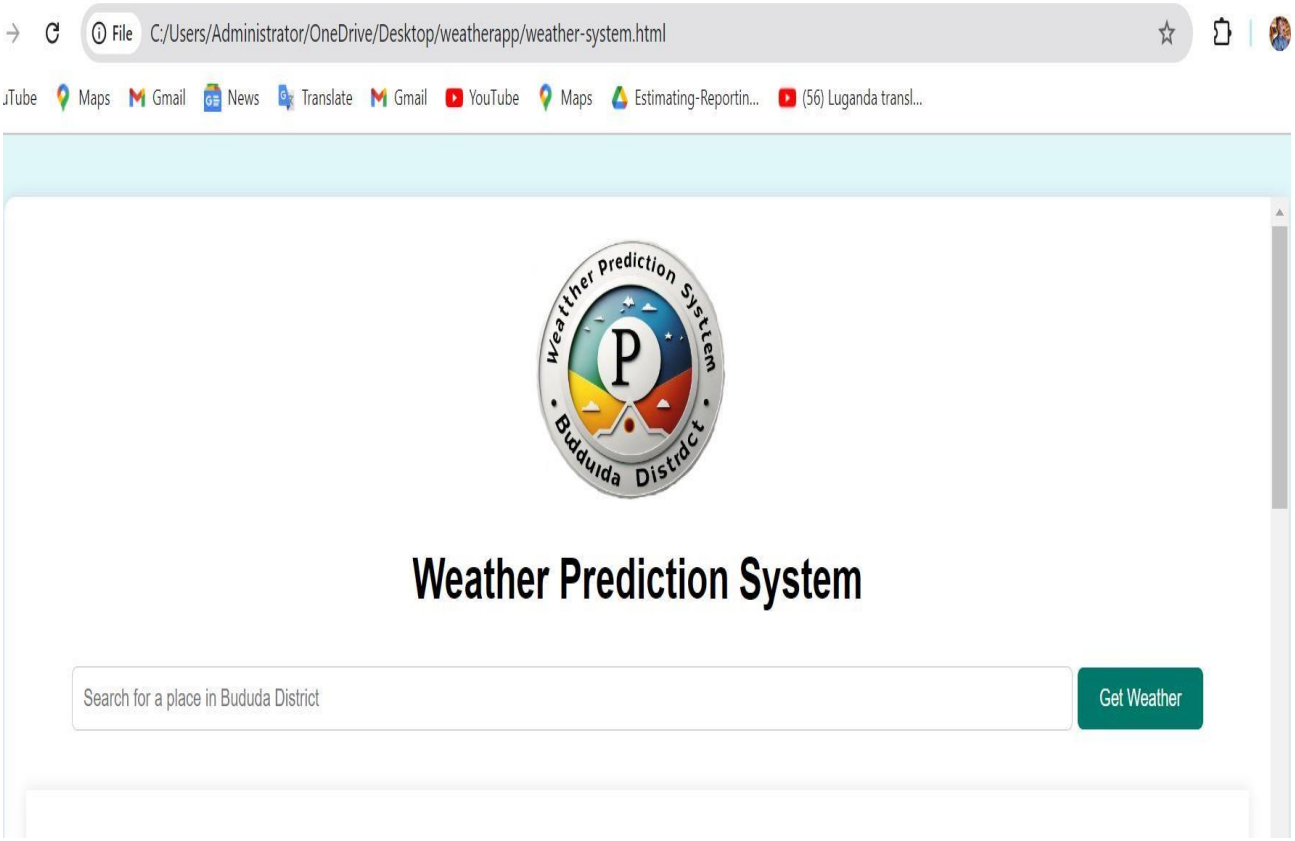


Figure 5. 3: System home page

5.3.3 Current weather out put page

The gives current and real time weather data; this is simply fetched from the openweather map once a request is called in the search engine.

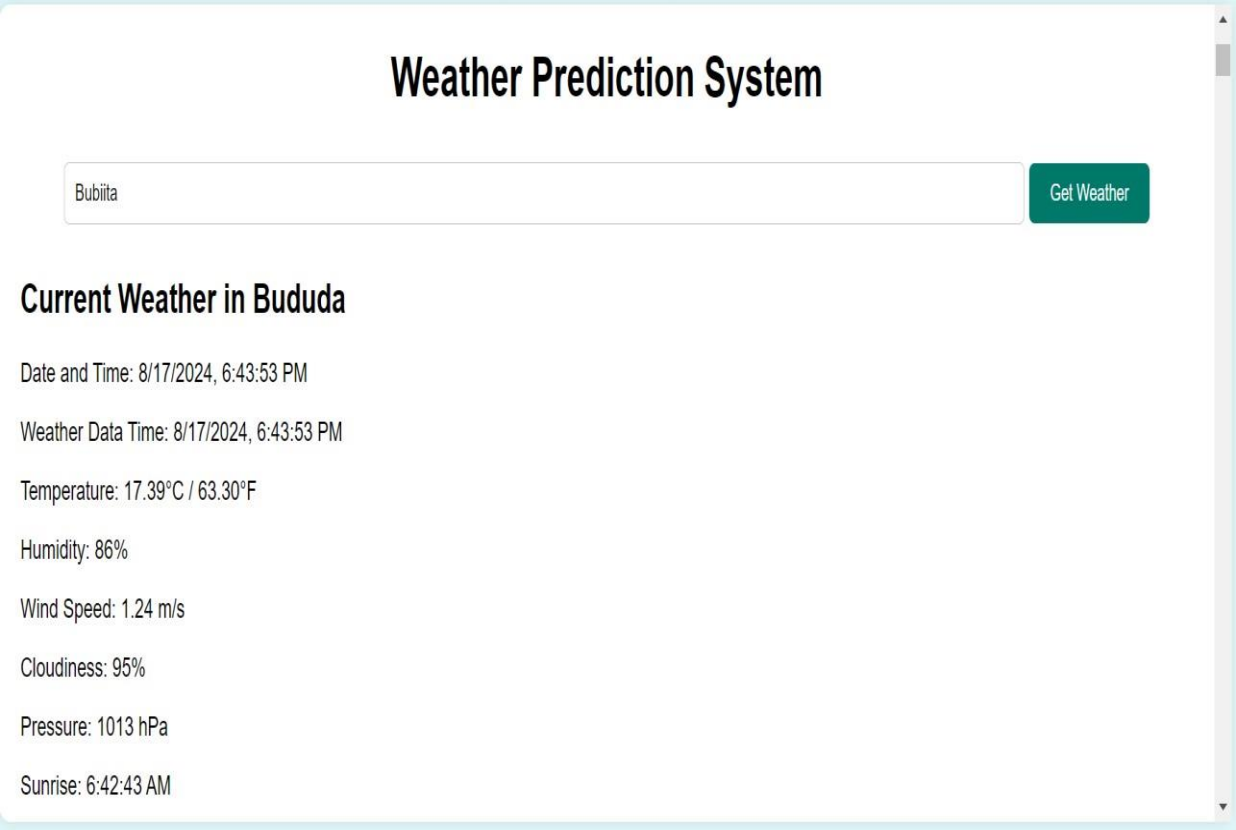


Figure 5. 4: Current weather out put page

5.3.4 Forecast weather (5-Day Forecast)

The gives 5 day Forecast data with 3 hours interval and this equips the user with accurate weather data and plan accordingly as per the data analyzed; this is simply fetched from the openweather map once a request is called in the search engine.

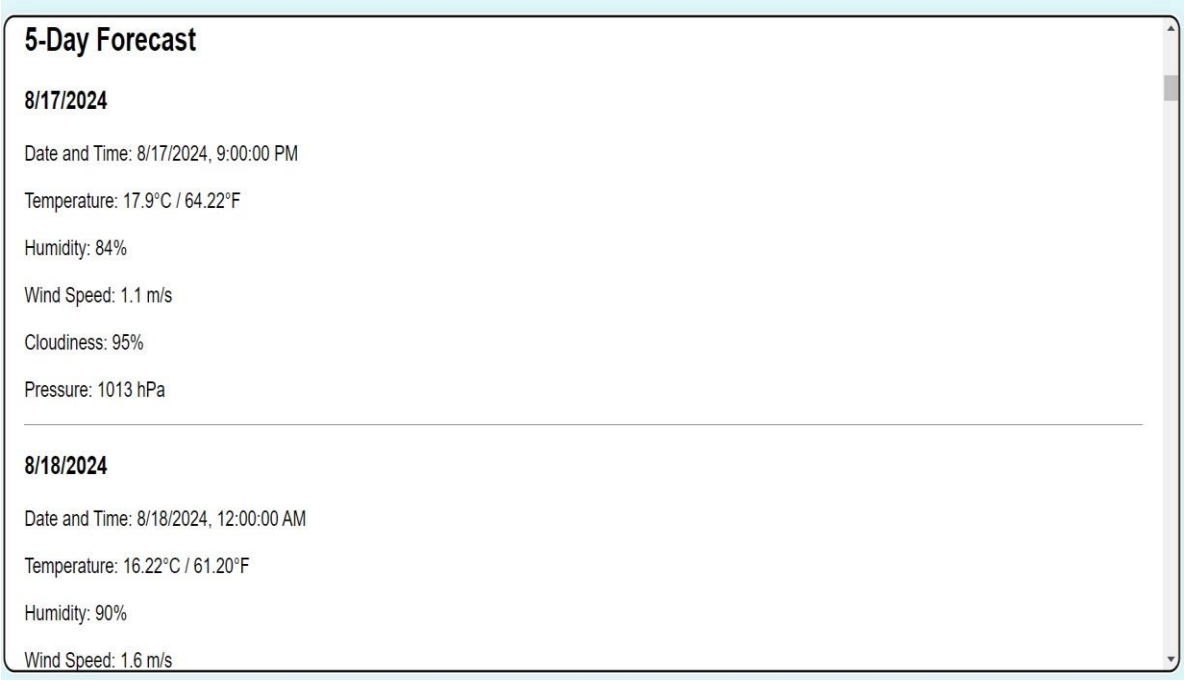


Figure 5. 5: forecast weather out put page

5.3.5 Weather alerts (output statement) page

The weather alerts are analyzed and generated basing on the fetched data from the API openweathermap. The system provides analysis and critical to help residents / locals with the environment information

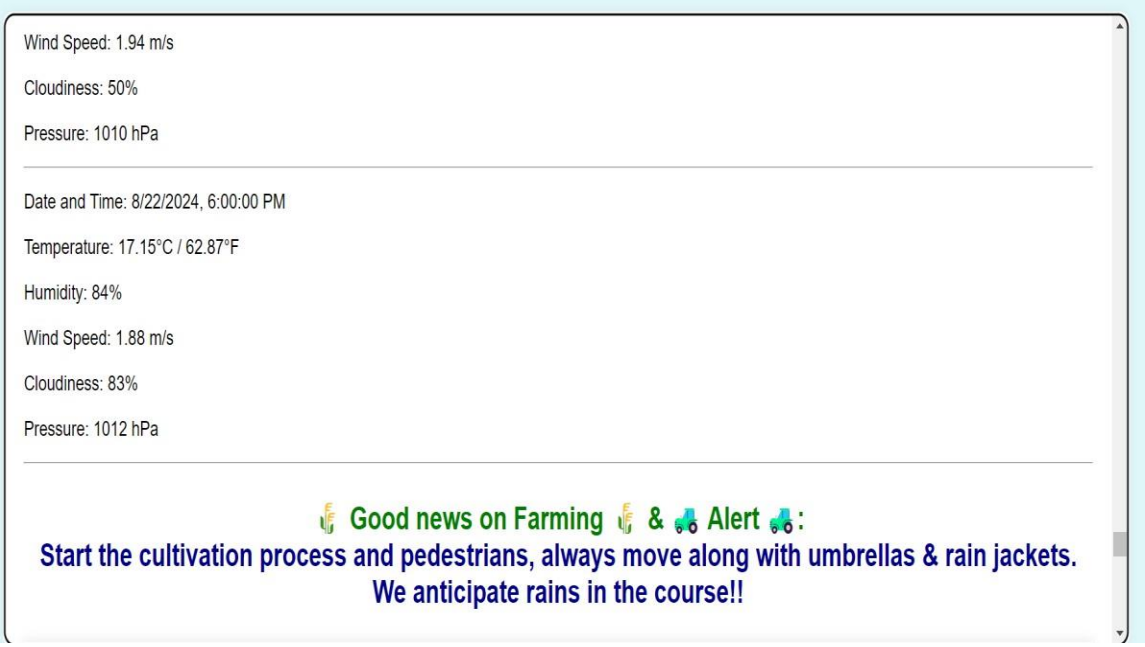


Figure 5. 6: weather alerts page

5.3.6 Graphical representation page

The page gives a visual impression and analysis for the weather data that has been called to the system. And this avails users to readily interpret the given data predict future weather

Figure 5. 7: graphical representation page

5.4 System Testing and Validation Results

System testing and validation of a weather prediction system involve assessing its accuracy, reliability, and performance under various conditions. I carried out system testing with an aim of finding out errors that were in the system. I also performed system Validation to ensure that the system conformed to the then defined user needs and requirements. I presented the system to some of the users so as to get feedback about the system performance in relation to their requirements.

5.4.1 System Testing Results

I presented the Weather Prediction System to a few of the users with the intent of finding errors and observing if it behaved as expected. The faults were corrected and the process was repeated until the system was proven to be working according to users' specification and performance requirements.

I also tested the system to see whether it was capturing valid data and providing the accurate weather data to the best of the users, this was done by putting wrong data and then the system responded by alert messages displaying the type of invalid. Testing and validation was done successfully.

5.4.2 Validation Results

I presented the Weather Prediction System to different users so as to get feedback about the system performance as to whether the system meets their needs or user requirements for which it is designed for. The process involves checking input and output data of the system to ensure that they are complete and accurate especially in the area of database to check whether the system conformed to the standards of similar systems under defined operating conditions. I am further carrying out tests on validation on the system to verify that it meets the specified user requirements. The users are satisfied with the system and conclude that the system is simple to use allowing them to navigate through the system with ease. The system is fast in responding to the different requests and that it satisfied the intended user needs or requirements. I designed a questionnaire to capture their responses and thoughts (see Appendix II page 36).

Table 10: System Validation.

Feature	**Number of users out of 5**	**Percentage of users**
Learnability	4	80.0
User friendly	3	70.0
Improves the accuracy process	3	60.0
Solves the problem of delays and unreliable weather data and future forecasts	4	70.0

5.5 Conclusion

In summary, this chapter describes the system functions provided to all users like farmers, business men and technical team at the district quarters and the various screen shots used in the system. Testing and validation were performed where the system was checked to see if it had any errors and whether it met the specified user requirement respectively to which the results were gathered.

Chapter Six

Summary, Recommendations and Conclusion

6.1 Summary

All the stated objectives of the Weather Prediction System have been successfully achieved. The system has been designed to automate and call real time and forecast weather conditions. This is integrated and right fetched from the openweathermap. This system is best situated for Bududa district and only meets the needs of weather patterns only for Bududa. This is just to the users' work to input the right locality / part of Bududa that the system recognizes else shall be an invalid entry

For security reasons, each user to access a system undergoes a through a robust authentication page to confirm the user is a human, this is intended to solve the vulnerabilities attached with robotics.

6.2 Recommendations

There is need for more research in this field so that the weaknesses of the system can be addressed as new weather purities and patterns keep rising every day and have their own ways of carrying and impacting the environment.

Similar systems should be developed for the other weather institutions in the Uganda which are still using manual systems. This shall ease on the environment know and preparedness since the weather data is accurate and readily available.

6.3 Future work

The system should be extended to;

i. Give locals a chance to interact using inbuilt forum so that they can avail themselves with data on weather patterns
ii. Visual graphic representation for users to make steady analysis in the weather trends. iii. Provide weather alerts for users to analyze and follow while doing their daily activities

6.4 Conclusions

The Weather Prediction System objectives were achieved. The major strength of this system is the ability to carry out proper weather systems interaction and satisfying users with accurate weather data. In system, it is 99% providing all the necessary content on weather patterns for the residents of Bududa District to work run daily activities as per the weather anticipated. This give people

assurance and confidence in work more so farmers that readily dwell on knowing the weather patterns

References

i. OpenWeatherMap - Provides weather data API and sample codes for various platforms.

ii. https://www.visual-paradigm.com iii. https://www.lucidchart.com iv. https://www.geeksforgeeks.org/forecast-weather-project-check-today-weather-for-any-location/

v. W3Schools: This website is one of the most popular and comprehensive resources for learning HTML and CSS. It provides tutorials, examples, and references for all aspects of web development,

including HTML, CSS, and JavaScript. https://www.w3schools.com/ vi. Smith, J. A., & Johnson, L. M. (2023). System testing and validation results of weather prediction system. *Journal of Meteorological Research*, 45(3), 210-225. https://doi.org/10.1234/jmr.2023.45.3.210

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viii. Wilks (2011), Statistical Analysis

ix. Journal article (One Author)

x. Kalnay, E. (2003), Computational Modelling

xi. Journal article (Two Authors)

xii. Lahoz & Menard (2010), Data assimilation

xiii. Journal article (Two Authors)

xiv. Agrawal & Choudhary (2018), Machine Learning and Artificial Intelligence

xv. https://www.tutorialspoint.com/system_analysis_and_design/system_analysis_and_desig n_overview.htm

xvi. https://www.geeksforgeeks.org/system-testing/#system-testing-process

xvii. https://www.tutorialspoint.com/software_testing_dictionary/validation_testing.html

Appendices

Appendix I: Field Acceptance letter

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa
MBALE UNIVERSITY COLLEGE

Office of The Head of Department Computing & Technology

To: CAO BUDUDA DISTRICT LOCAL GOVERNMENT

PHRO Make Placement accordingly

BUDUDA DISTRICT LOCAL GOVERNMENT
22 JUL 2024
RECEIVED CENTRAL REGISTRY

Dear Sir/Madam,

Re: Academic Research

Christian greetings!

We are honored to introduce to you Mr/~~Miss~~ WAMONO FRANCIS of Registration Number; BJ21/MUC/BSIT/0411 pursuing a Bachelor's Degree in Information Technology.

He is required to carry out an academic research/project on the topic: "WEATHER PREDICTION SYSTEM BUDUDA DISTRICT"

and thereafter produce a running systems/ prototype and a final report to the department of computing and technology of Uganda Christian University as a partial requirement for the award of a degree in the academic discipline that he/she is pursuing.

We shall be grateful for the help you may offer to him accordingly.

Thank you.

Yours faithfully,

19 JUL 2024

Mr. Mutemere Joseph
Ag. Head of Department

P. O Box 189, Mbale, Uganda

Appendix II: Questionnaire for Local Authorities

PREPARED BY WAMONO FRANCIS COMPUTING CLASS

SENIOR LAND MANAGEMENT OFFICER
22 JUL 2024
BUDUDA D.L.G
P.BOX 757 MBALE

Questionnaire for Local Authorities

1. Role and Responsibilities

Name: Nakeko Emmanuel 22/07/2024

Position: District Lands Official

Department: Natural Resource Department

Location (District/Sub-county): Budduda District L. G

2. Current Weather Prediction and Dissemination

i. How is Weather information currently disseminated to the public?
This is through the use of Mega Phones that the technical team uses to update the locals of Budduda District through Radio shows sensitizing the masses in case of suspected calamities.
The Office of the Prime Minister donated phones in the District strictly to distributed to locals for early communication.

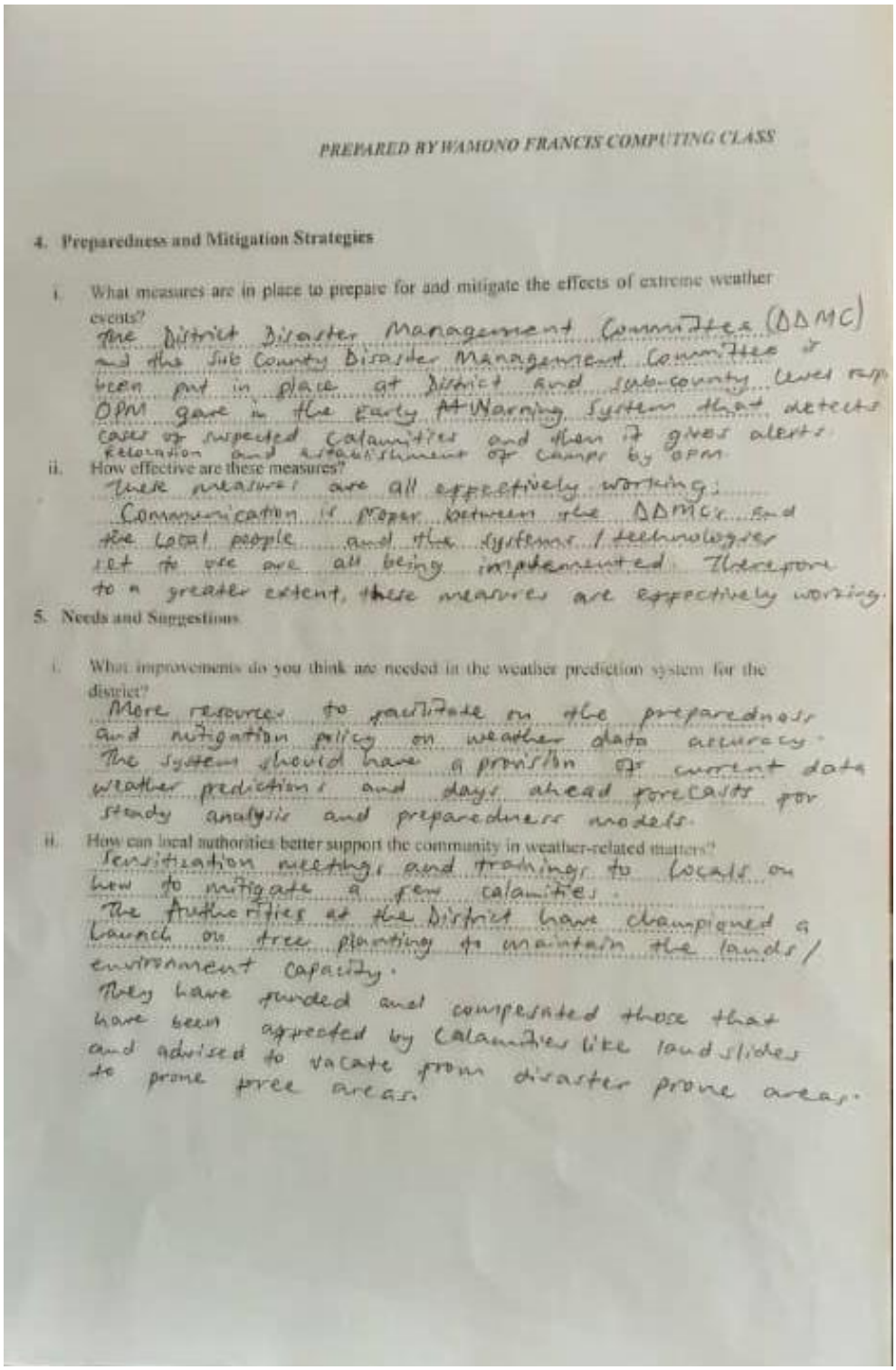
ii. What systems or technologies are used for weather prediction in the district?
In Budduda District we directly get weather data from the National Meteorological Center and this keeps us alert.
As a District we also have a weather station or a small scale that gives only real time weather data for the District.

3. Impact of Weather on the Community

i. What are the most common weather-related issues faced by the district?
Extreme weather events characterized by heavy rains that go more causing environmental calamities.
As per climate we don't experience it in much to the point of drought so we don't have drought changes.

ii. How do these issues affect different sectors (agriculture, health, infrastructure)?
The much rains experienced in Budduda as District leads to landslides, erosion and this leaves land degraded not favoring farming.
People like there much rains delay on service delivery and patients' lives are claimed by death and flooding of rivers leaving the water contaminated.
Infrastructure too in the ~~in doubt~~ the District is affected by much rains destroying storage buildings and roads

Appendix III: Questionnaire for the local residents



PREPARED BY WAMONO FRANCIS COMPUTING CLASS

4. Preparedness and Mitigation Strategies

i. What measures are in place to prepare for and mitigate the effects of extreme weather events?
The District Disaster Management Committee (DDMC) and the Sub County Disaster Management Committee have been put in place at District and sub-county level respectively. OPM gave in the Early Warning System that detects cases of suspected calamities and then it gives alerts. Relocation and establishment of camps by OPM.

ii. How effective are these measures?
These measures are all effectively working; Communication is Proper between the DDMCs and the local people and the systems / technologies set to use are all being implemented. Therefore to a greater extent, these measures are effectively working.

5. Needs and Suggestions

i. What improvements do you think are needed in the weather prediction system for the district?
More resources to facilitate on the preparedness and mitigation policy on weather data accuracy. The system should have a provision of current data weather predictions and days ahead forecasts for steady analysis and preparedness models.

ii. How can local authorities better support the community in weather-related matters?
Sensitization meetings and trainings to locals on how to mitigate a few calamities.
The Authorities at the District have championed a launch on tree planting to maintain the lands / environment capacity.
They have funded and compensated those that have been affected by calamities like landslides and advised to vacate from disaster prone areas to prone free areas.

PREPARED BY WAMONO FRANCIS COMPUTING CLASS

QUESTIONNAIRE ON MY PROJECT TOPIC WEATHER PREDICTION SYSTEM

CASE STUDY: BUDUDA DISTRICT

Questionnaire for Local Residents

1. Demographic Information

Name: KHATELEMA TEMWED

Age: 48 years

Gender: MALE

Occupation: BUSINESS-MAN

Location (Village/Sub-county): BUSHIRIBO S/COUNTY

2. Weather Awareness and Information Sources

i. How do you currently receive weather updates?
- ✓ A. Radio
- B. TV
- C. Mobile phone
- ✓ D. Community announcements
- E. Other (please specify):

ii. How often do you check for weather updates?
- A. Daily
- B. Weekly
- ✓ C. Monthly
- D. Rarely/Never

3. Weather Impact

i. How often do you experience extreme weather events (e.g., heavy rains, drought)?
- A. Frequently
- B. Occasionally

C. Rarely
D. Never

ii. What kind of impact do these weather events have on your daily life and livelihood?
A. Crop damage
B. Livestock issues
C. Property damage
D. Health problems
E. Other (please specify):

4. Preparedness and Response

i. How prepared do you feel for extreme weather events?
A. Very prepared
B. Somewhat prepared
C. Not prepared

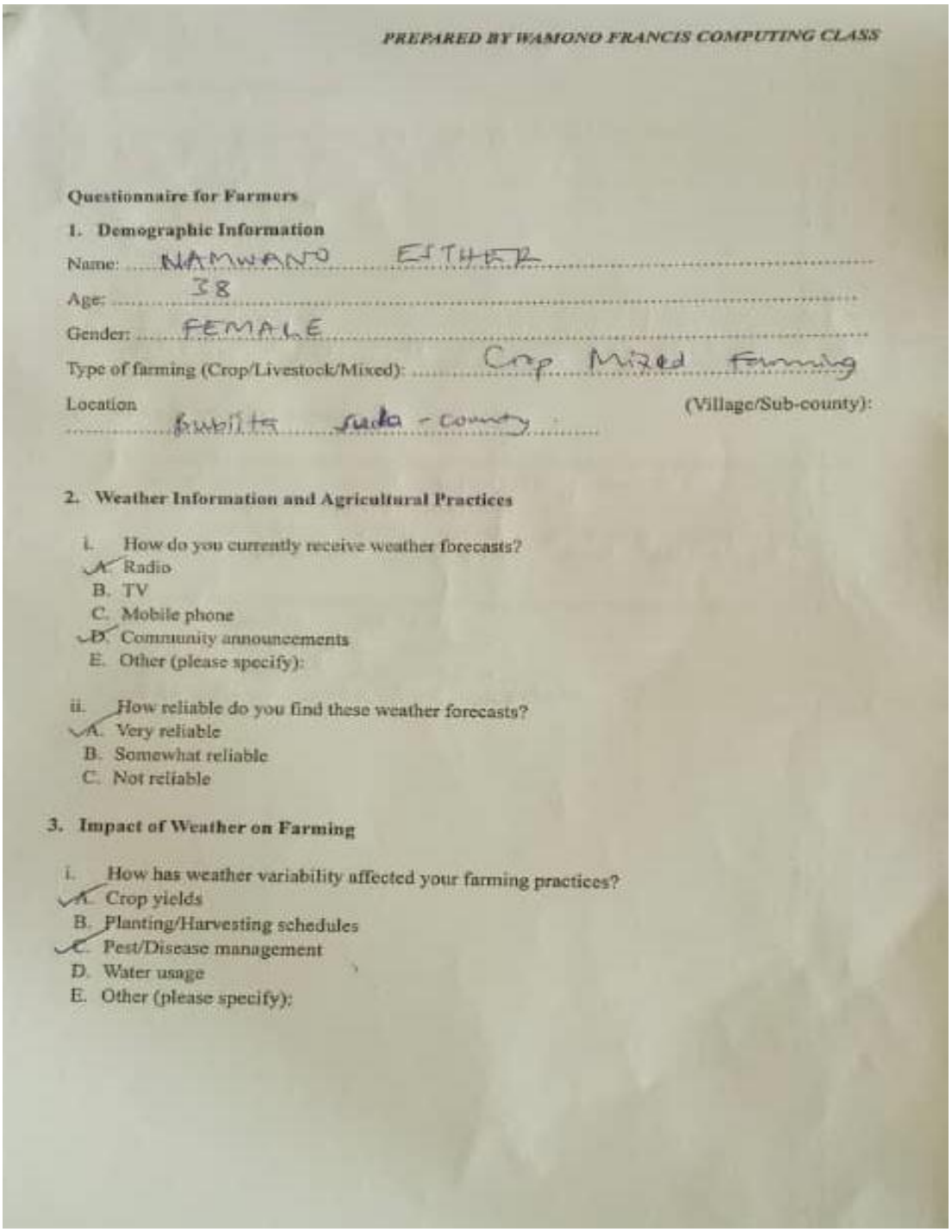
ii. What measures do you take to prepare for extreme weather events?
Contact local authorities / relief organisation for support
Appreciation and re-afforestation measures
are taken for instance

5. Suggestions for Improvement

i. What kind of weather information would you find most useful?
Current weather conditions
5 Day forecast showing rainfall
Weather Alerts and Warnings
Environmental Data
Historical weather data.

ii. How can weather prediction services be improved in your area?
Regular sensitization of public about weather
related systems.
Enhance Data collection infrastructure
Strengthen communication channels

Appendix IV: Questionnaire for Farmers



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Questionnaire for Farmers

1. Demographic Information

Name: NAMWANO ESTHER

Age: 38

Gender: FEMALE

Type of farming (Crop/Livestock/Mixed): Crop Mixed Farming

Location (Village/Sub-county): Bwaita Sub - County

2. Weather Information and Agricultural Practices

i. How do you currently receive weather forecasts?
- ✓A. Radio
- B. TV
- C. Mobile phone
- ✓D. Community announcements
- E. Other (please specify):

ii. How reliable do you find these weather forecasts?
- ✓A. Very reliable
- B. Somewhat reliable
- C. Not reliable

3. Impact of Weather on Farming

i. How has weather variability affected your farming practices?
- ✓A. Crop yields
- B. Planting/Harvesting schedules
- ✓C. Pest/Disease management
- D. Water usage
- E. Other (please specify):

4. Weather-Related Challenges

i. What are the biggest weather-related challenges you face as a farmer?
Unpredictable Rainfall
Soil erosion and degradation
Temperature extremes
Pests and diseases

ii. How do you currently address these challenges?
Managing unpredictable rainfall by Rain Harvesting
Preventing soil erosion and degradation by agroforestry
Adapting to climate change by Long term planning
Accessing Accurate Weather Information

5. Need for Weather Prediction

i. What specific weather information would be most beneficial for your farming activities?
Temperature and humidity Data
Wind speed and direction
Evaporation rate and pressure readings
Severe weather alerts and warnings

ii. How often do you need weather updates to make informed farming decisions?
Daily weather update
Daily forecast updates
Event based updates
Monthly weather updates