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Data Mart of Climate Changes: A Proposed Approach to Support Sustainable Decision-Making

Alaa Khalaf Hamoud, Abdul-Haleem Ali Al Muhyi **, Sadiq Salim Abdullah **, Jasim Mohammed Dahr ****

*Department of Cybersecurity, University of Basrah, Iraq
** Marine Science Center, University of Basrah, Iraq
***Directorate of Education in Basrah, Basrah, Iraq
*Corresponding Email: alaa.hamoud@uobasrah.edu.iq

ABSTRACTS

The increasing interest in climate changes necessitates different effective solutions of data-driven decision-making in order to promote sustainability. In this paper, a proposed framework of data mart model designed to manage and analyze dataset of climate change in a station in Basrah, Iraq. The main aim is to examine the proposed data mart for support sustainable decisions by diving in different factors such as temperature, solar radiation, rain, wind speed at (10, 30, 50, 52) meters, wind direction, and humidity. The proposed schema for data mart is star schema to facilitate on-line analytical processing operations (roll up and drill down) through hierarchy of date, and for future advanced analytics. ower BI is utilized to create dashboards for data visualization, delivering actionable insights to environmental researchers, decision-makers, and stakeholders. The model showcases real-time indicators and customizable dashboards, aiding stakeholders in making short-term decisions on climate change impacts. Future work involves incorporating diverse climate datasets and predictive machine learning models to forecast patterns supporting sustainability.

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1. INTRODUCTION

Climate change is considered as one of the most challenges in our time, where it affects lifetime systems such as economic, social, and environmental sectors. To handle this challenge and to accurately make strategic decisions, it is required accurate, comprehensive, and timely data. However, the complex diverse nature of climate data with different metrological patterns, sea-level changes, rainfall level, solar cycles, greenhouse gases, volcanic activities, and more other factors may present significant hurdles to decision-makers who need actionable insights (Shah et al., 2024; Jain et al., 2023). The field of data warehousing proves its actionable results in decision-making process within different fields such as healthcare (Sahama & Croll, 2007; Teixeira et al., 2015), education (Namnual et al., 2019), cloud computing (Ferreira et al., 2017), industries (Reddy et al., 2010), banking and finance (Dhingra, 2018), retail and E-commerce (Nwanakwaugwu et al., 2023), telecommunication (von Lubitz & Patricelli, 2007), government and publica service (Doutreligne et al., 2023), and many other sectors. Data warehousing is the field of implementing data warehouse (DW) or data mart for decision making.

The implementation cycle starts with reading data from different data sources with different shapes, converting them to a unified shape throughout data integration and extraction, transformation, and loading (ETL) process, then using these resulting information-based reports in decision-making process (Roy et al., 2024; Zhu, 2024). Data mart is a subset of DW where the main aim of using data mart is to support departmental short-term decision-making, while DW takes long time, and huge resources to implement (Farhan et al., 2024; Khan et al., 2024). The data mart can be implemented in a short time with little resources and focused on the departmental data. The other aim of using data mart is to discover the ability to implement the DW since DW utilized all organizational data, so it can be considered as efficient solution since it is tailored to specific department and specific needs of decision-making (Hamoud et al., 2021; Najm et al., 2022; Zhang et al., 2023).

The climate data mart will enable decision-makers and stakeholders (such as researchers, policy makers, environmentalists, and managers) to analyze and quickly access to different environmental datasets. Using data mart for climate change will help in visualizing climate impacts, empowering evidence-based decisions, and assisting in making short-term strategic and sustainable decision (da Cunha et al., 2023; Gad et al., 2017; Ugonnia et al., 2024). In this paper, a model-based data mart is proposed to trace the climate change, wind speed, wind direction, pressure, solar radiation, temperature, and rainfall levels based on a dataset from a station situated at the Harir station, located on the banks of the Al-Mashab River in Al-Haritha, north of Basrh, Iraq. The implementation process includes data quality insurance, ensuring data consistency, performing data integration in order to formulate user-friendly reports for data analysis. There are many objectives of the proposed data mart, such as:

1. Implementing short-term data repository to store the collected data from weather tower in (Harir station), to support short-term decision making.

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2. This data mart will be extended to be centralized repository to archive data from different stations.

3. Provide a platform for future long-term decision making and find the relationship among different variables such as (solar radiation, wind speed, wind direction, and rain).

4. The implemented data mart will ensure the data security and privacy of the collected data, and allow the authorized access to the data.

5. The proposed data mart will enable integrating with different models of weather forecasting, and geographical information systems.

The rest of the paper is organized as follows: section 2 lists and discussed the literature review, section 3 explained the proposed model, section 4 discussed how to implement the proposed model, while section 5 and the results concluded, while section 4 discussed the predefined report, and how they are important for decision-making process. The final section lists all the future works and conclusions.

2. METHOD

For storing the features of climate data of National Climatic Data Center, Hasan Hashim in (Hashim, 2020) proposed a data modeling framework to implement hybrid data warehouse in order to enable data pattern identification, and assist the decision-making related to agricultural stakeholder. The proposed data warehouse considered as an essential tool to help the researchers in the field of climate-change studied by discovering the important weather patterns for recommending the required actions by experts, and making plans accordingly. The data warehouse can be considered as a platform for decision-making which can be utilized to implement different machine learning algorithms such as the data warehouse proposed by Dana Shahin et al. in (Shahin et al., 2021). Based on the proposed data warehouse, a dashboard is designed to provide prediction capabilities based on machine learning algorithms in order to predict the weather.

The data warehouse implementation framework proposed by Hanan Balti et al. in (Balti et al., 2022) is a multi-dimensional framework that includes three parts, the first part includes data preprocessing, and collection, while the second part includes storing, loading, and transferring the data into big data platform, while the third part includes visualizing, and interpreting the data. The aim of the framework is essential for spatio-temporal analysis where the decision-makers can monitor the dropout disaster effects. The data utilized in the proposed framework includes climatological data, biophysical data, and remote sensing data. The results revealed that the proposed framework has a fast retrieval speed with high elasticity of different requests compared with other frameworks.

Georgia Garani et al. (Garani et al., 2022) are proposed data warehouse based on hybrid schema, including all the historical data. The data are consisting of operating airports data and the data of flight delays, and cancellations from Greek flight information region in Greece. SQL is utilized to retrieve the data, make them accessible, and manageable. Different classification techniques are implemented to allow

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flexible scheduling, and planning in order to minimize the waiting time, and to increase passengers' satisfaction. Abderrahim El Mhouti et al. in (El Mhouti et al., 2022) proposed a model based on Web Scraping framework that extract data to be used in descriptive analysis process, and to improve decision-making process in forecasting weather. Many steps are implemented for web scraping process such as data extraction, archiving, filtering, and analysis. The proposed model allows restoring the data to present the statistical reports in a customized dashboard. The results conducted in the study showed the ability of the proposed system to predict the variables of the weather (temperature, precipitation, and humidity), and to support decision-making process. (Djiroun et al., 2023) suggested DW enrichment approach using open data and natural language processing. The internal and external open data, Google data, web scraping and natural language processing were utilized to ingrate external data into DW. The aim is enhancing business intelligent systems by integrating external data into DW for better decision-making. Table (1) discussed the literature review shows the literature related to using data warehousing in decision making process related to climate change.

Table 1. Literature Review.

Author(s)	Proposed Framework	Data Utilized	Key Features	Results
Hasan Hashim (Hashim, 2020)	Hybrid DW	Data from Climate Data Center, Saudia Arabia.	Enables identification of data pattern and assists decision-making related to agricultural sector.	• Supporting climate-change research. • Facilitating planning and actions based on weather patterns.
Dana Shahin et al. (Shahin et al., 2021)	DW integrated with machine learning	Historical weather data covering 17 regions in Jordan.	Predictive capability using machine learning.	• Dashboard for weather prediction.

Table 1 (continue). Literature Review.

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Author(s)	Proposed Framework	Data Utilized	Key Features	Results
Hanan Balti et al. (Balti et al., 2022)	Multi-dimensional DW	Remote sensing, climatological, and biophysical data in China.	Data preprocessing, integration, visualization, and interpretation platform.	• Fast retrieval speed. • Spatiotemporal analysis.
Georgia Garani et al. (Garani et al., 2022)	Hybrid schema-based DW	Historical data of Greek flight information in Gereek.	Flexible planning and scheduling through SQL classification and retrieval.	• Flexible scheduling. • Flexible planning. • Minimizing wait time of passengers.
Abderrahim El Mhouti et al (El Mhouti et al., 2022)	Weather forecasting based on web scraping.	Weather, humidity, and precipitation data from website data.	Extract, filter, archive, and analyze data.	• Predict weather variables. • Support statistical reporting.
Rahma Djiroun et al. (Djiroun et al., 2023)	DW enrichment using open data and natural language processing.	Internal and external open data	Google data, web scraping and natural language processing to ingrate external data into DW.	• Enhancing business intelligent systems by integrating external data into DW for better decision-making.

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3. METHODOLOGY

The implementation process of the proposed data mart is presented in Figure 1. The framework started with data preprocessing which includes data visualizing and assessment. The data profiling step includes all process of examining, and summarizing dataset to analyze the structure of data, performing descriptive analysis, and for quality assessment. The process of building the proposed schema of data mart for future implementation of DW is the next step. The model implementation and report building will be performed based on Power BI. The resulting predefined, customized, and KPI reports will be the result of Power BI. The final step is measuring the implementation of reports and how their results important for decision-making process.

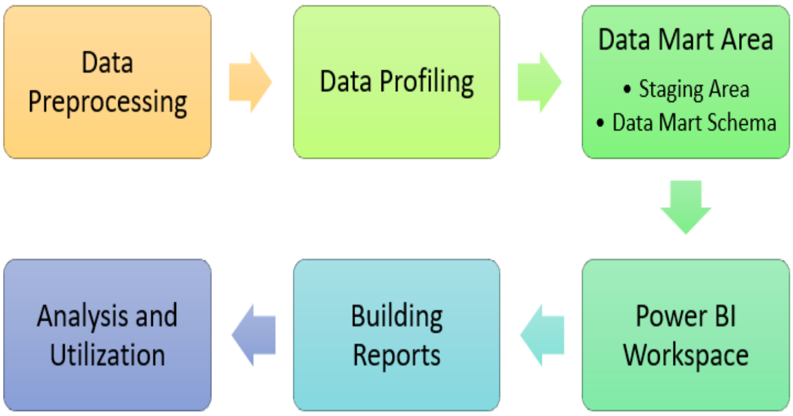

Fig. 1. Methodology Framework.

The data preprocessing step includes data visualization and preparing data for the next analysis. The data source used in data model implementation is a dataset of data collected from weather station. The weather tower is situated at the Harir station, located on the banks of the Al-Mashab River in Al-Haritha, north of Basrah, as shown in Figure 2. This station features a study center and a marina for Al-Haritha (Mashahif) boats, allowing tours in the eastern Hammar Marsh, an area classified as a World Heritage Site.

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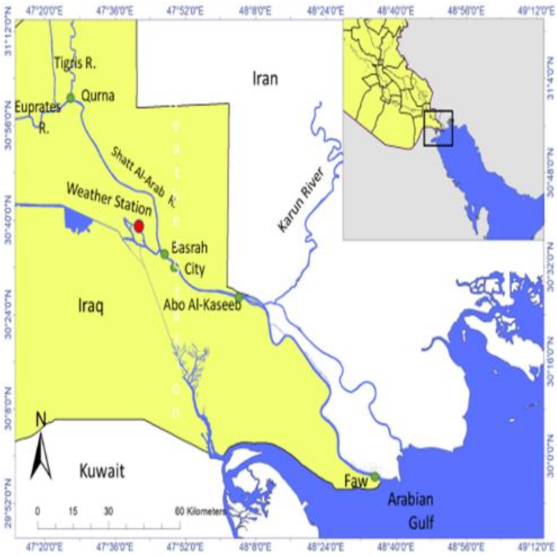

Fig. 2. Location of Weather Station.

The weather tower in Al-Haritha's Al-Mandhuri area belongs to the Marine Sciences Center. It is one of eight towers distributed across the following governorates: Basra, Nasiriyah, Samawah, Kut, Najaf, Karbala, Wasit, and Diwaniyah. These towers are dedicated to studying wind energy in Iraq. The dataset consists of (133,089) row data that monitors various atmospheric elements every 10 minutes, including:

- Horizontal wind speed at altitudes of 10 m, 30 m, 50 m, and 52 m.
- Vertical wind speed at altitudes of 10 m, 30 m, and 50 m.
- Wind direction at altitudes of 8 m, 28 m, and 48 m.

Additionally, at an altitude of 2 meters, the towers measure other atmospheric elements, including (Solar radiation, atmospheric pressure, relative humidity, temperature, and precipitation). The result of data profiling step for the dataset are listed in the following Table (2).

Table 2. Metadata of the Dataset.

Seq	Columns	Null Value	Min Value	Max Value
1	Rain	0	0	67
2	Min Pressure	0	95.9	102.9
3	Max Pressure	0	103	110.3
4	Min Solar	0	0	452.3
5	Max Solar	0	0	1200.3

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6	Date	0	10-1-2016	9-8-2020

Table 2 (continue). Metadata of the Dataset.

Seq	Columns	Null Value	Min Value	Max Value
7	Min Temperature	0	-14.25	154.7
8	Max Temperature	0	-4.75	154.7
9	Min Wind Speed at 10 M	0	0.35	10.1
10	Min Wind Speed at 30 M	0	0.39	13.9
11	Min Wind Speed at 50 M	0	0.32	17.1
12	Min Wind Speed at 52 M	0	0.35	16.2
13	Max Wind Speed at 10 M	0	0.35	26.4
14	Max Wind Speed at 30 M	0	0.39	27.8
15	Max Wind Speed at 50 M	0	0.32	51
16	Max Wind Speed at 52 M	0	0.35	81.3

Next, many data preprocessing steps are performed such as:

- The datetime column data was transformed from text into date data type in order to implement the hierarchy (year→Quarter→Month→Day). This hierarchy will enable roll-up and drill down operations that can help in deeply analyze the data from different perspectives.
- The categories of wind speed for heights (10, 30, 50, 52) meters are derived based on the table () and according to Beaufort Wind Scale (2021).
- The category of rainfall is derived on the table (3) and according to Beaufort Wind Scale (2021).

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Table 3. Wind Speed categories according to medium wind speeds according to Beaufort Wind Scale (2021).

Factor	Measure	Description
Wind Speed	0-0.2 (m/s)	Calm (C)
	0.3-1.5 (m/s)	Light Air (LA)
	1.6-3.3 (m/s)	Light Breeze (LB)
	3.4-5.4 (m/s)	Gentle Breeze (GB)
	5.5-7.9 (m/s)	Moderate Breeze (MB)
	8.0-10.7 (m/s)	Fresh Breeze (FB)
	10.8-13.8 (m/s)	Strong Breeze (SB)
	13.9-17.1 (m/s)	Near Gale (NG)
	17.2-20.7 (m/s)	Gale (G)
	20.8-24.4 (m/s)	Severe Gale (SG)
	24.5-28.4 (m/s)	Storm (S)
	28.5-32.6 (m/s)	Violent Storm (VS)
	>32.7 (m/s)	Hurricane (H)
Rain	0 (mm)	No rain (N)
	0.1-0.9 (mm)	Very Light (VL)
	1-10 (mm)	Light (L)
	11-30 (mm)	Moderate (M)
	31-70 (mm)	Heavy (H)
	71-150 (mm)	Very Heavy (VH)
	>151 (mm)	Extremely Heavy (EH)

The DW is a centralized repository that used to store large amount of data from different sources. The main aim is analysis data and answering and formulate queries required for decision-making and not for transaction process (Costa et al., 2018; Kimball et al., 1998). In the other hand, data mart is a subset of DW that used to implement analysis and query processing for specific domain and department. The data in the data mart is filtered, and summarized for fast access. The implementation cycle of data mart is very short compared to DW, and that

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why it is used for short-term decision making (Hamoud et al., 2020) (DAHR et al., 2022). The basic structure of DW implementation consists of star, snowflake, or fact-constellation schema. The aim of using star schema over other schemas are (Gopalkrishnan, 1999):

- Simple design, fast query speed and processing.
- Maintainability and easy to implement.
- Optimized for on-line query processing (OLAP).
- Easy to understand and read.

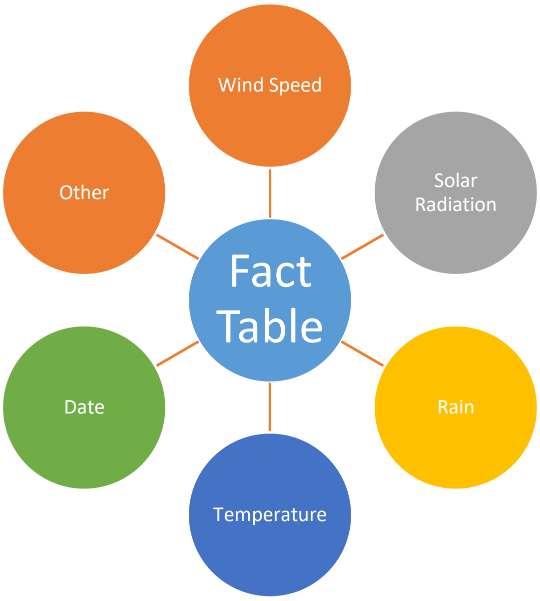

Fig. 3. Proposed Star Schema.

The proposed schema in Figure (3) consists of six dimensions (date, temperature, wind speed, rain, solar radiation, and other). The proposed schema allows future expanding of dimensions, and integrates real-time data which allows real-time analysis and decision-making. It permits adapting new business intelligence solutions such as implementing machine learning algorithms and optimizing the results by incorporating external data sources from different stations in different locations. The next step in visualizing data in Power BI (2.138.782.0) on a platform with the properties listed in Table (4).

Table 4. Platform Properties.

Property	Description
Processor	Intel Core-I 5 gen6 64bit
CPU	2.4 GHZ
RAM	12GB
HARD	476 G SSD
OS	Windows 10 Pro
GPU	Intel HD Graphics 520

The next step is implementing data visualizing and implementing reports

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using Power BI. One of the powerful BI tools is Power BI which developed by Microsoft. This tool enables data visualization and analysis by navigating different data sources, allows user to transform raw data into a consolidate shape in order to provide meaningful insights. This tool allows building interactive reports and dashboards to visualize information in different charts. Power BI integrates different shapes of data and integrated range of formats with different Microsoft services such as Excel, SharePoint, Azure, and many other platforms. It is an easy and friendly user interface which provides different analytical tools such as Data Analysis Expressions (DAX), machine learning, and different data warehouse navigating operations of OLAP such as (roll-up, and drill down). Power BI with cloud-based service allows real-time data navigating and collaboration, and makes it a popular choice for different organizations seeking decision-making efficiently (Becker & Gould, 2019; Metre et al., 2024).

4. RESULTS AND DISCUSSION

This section will discuss the predefined reports that help the stakeholder in making their decisions according to specific selection criteria. Five dashboard reports are listed, where many other reports can be implemented according to stakeholders' requirements and needs. The dashboard in Figure 4 demonstrates the count of wind speed at 10 meters according to selection criteria (year, and month). The user can compare the categories of wind speed according to specific month(s) in multiple or single year. The aim of this dashboard is helping the decision-makers to evaluate the wind speed for energy production in the station address. These results can also help in future weather forecasting, produce early warnings, and damage risks.

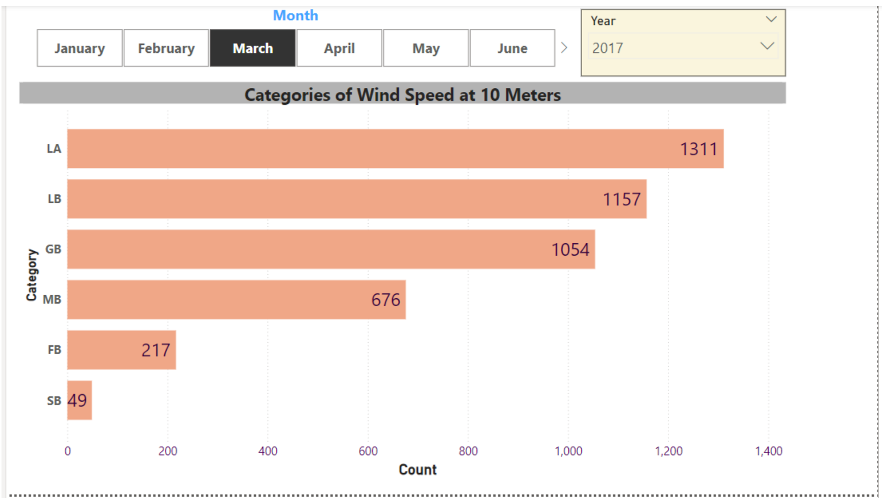

Fig. 4. Dashboard of Categories of Wind Speed at 10 10 Meters.

The aim of the dashboard in the Figure (5) is to derive effective insights related to decision-making in the fields starting from understanding rainfall patterns, and determining the annual, seasonal, and daily patterns of rainfall. Based on the dashboard, the comparison can be implemented to show average rainfall according to specific seasons, and for different years which help in observing the climate changes. The results can also help in determining the optimal planting

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and risks about the low or high rainfall. The important of measuring rainfall can also affect the plans of storing or releasing water, which as a result affect the resource planning, and sustainable solutions.

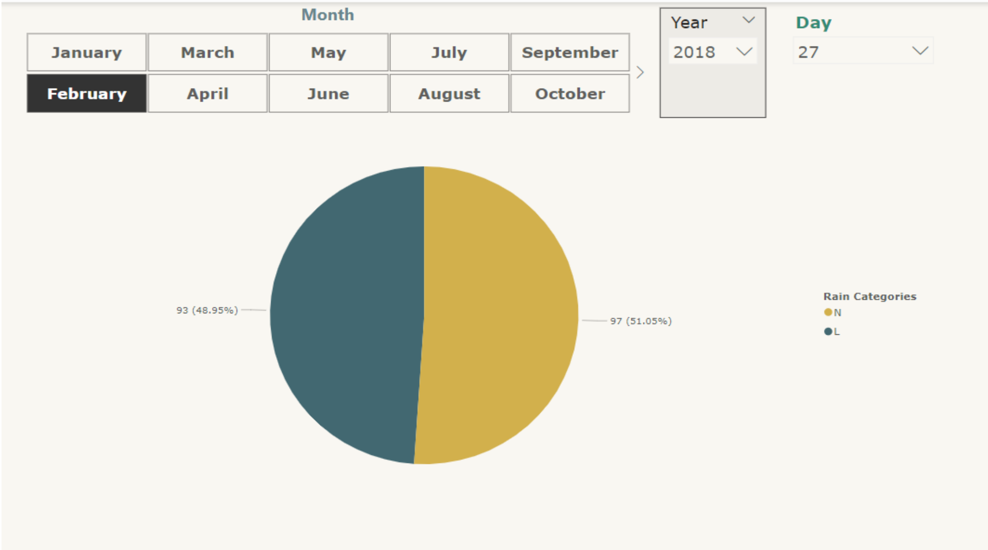

Fig. 5. Daily Rainfall Categories.

The results of implementing dashboard in Figure (6) can help to compare the daily rainfall with average wind speed at 10 meters/second based on drill-down operation (from year to month to day) and rollup operation (from day to year). The results can show the comparison of daily rainfall compared with average categories of wind speed. These results can affect agricultural activities, and outdoor events. The results can help also in visualizing the correlation between wind speed categories, and rain category for future prediction

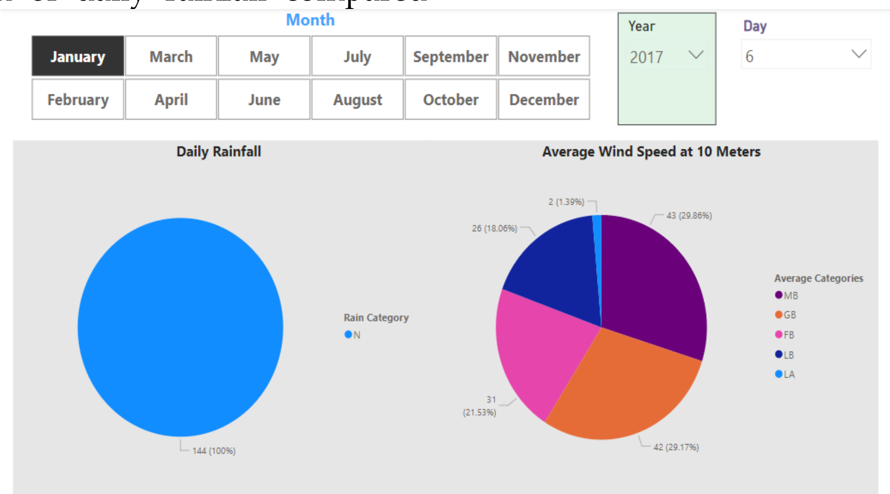

Fig. 6. Daily Rainfall Categories.

Using KPIs can help in giving warnings according to current rates.

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These readings can help in measuring monthly wind speed according to (10, 30, 50, 52) meters, where they can help in determining the safety conditions, producing warnings, evaluating speed to energy production, and compare average wind speed with different heights. The results can help in determining steady wind speed for energy production turbines, and planning urban layouts that mitigate wind speed issues and shown in Figure 7.

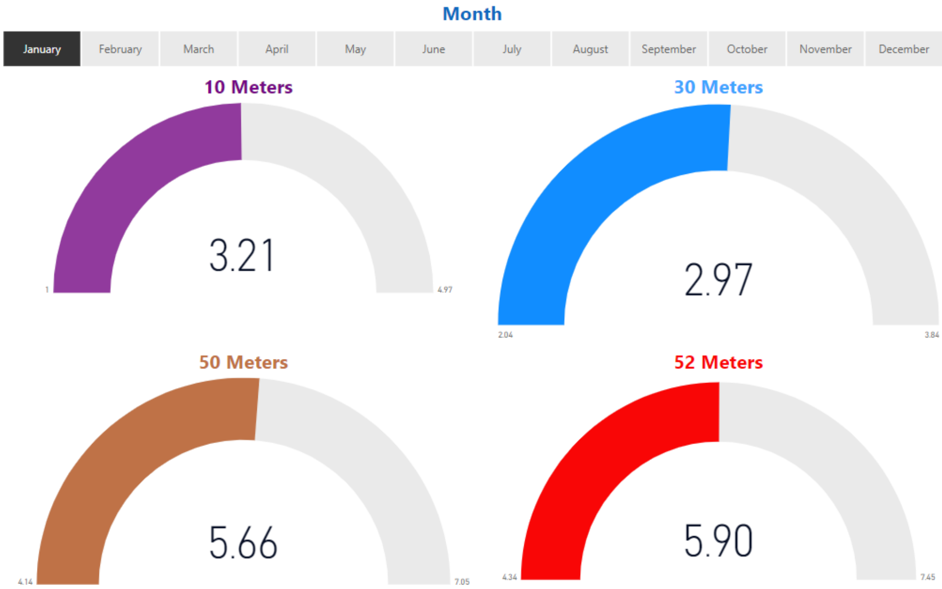

Fig. 7. KPIs of Wind Speed.

The final dashboard in Figure 8 demonstrates the accumulative rainfall according to month. Thee result show that there is a variance in cumulative rain in months (November, February, and March) in year 2017. Winter season in 2017 faced that the rain stopped in months (December, and January). This dashboard can help in visualizing the accumulative rain rates according to month(s) annually. The result conducted can help in measuring the seasonal rates of rain and compare them according to months which visualize the climate changes annually.

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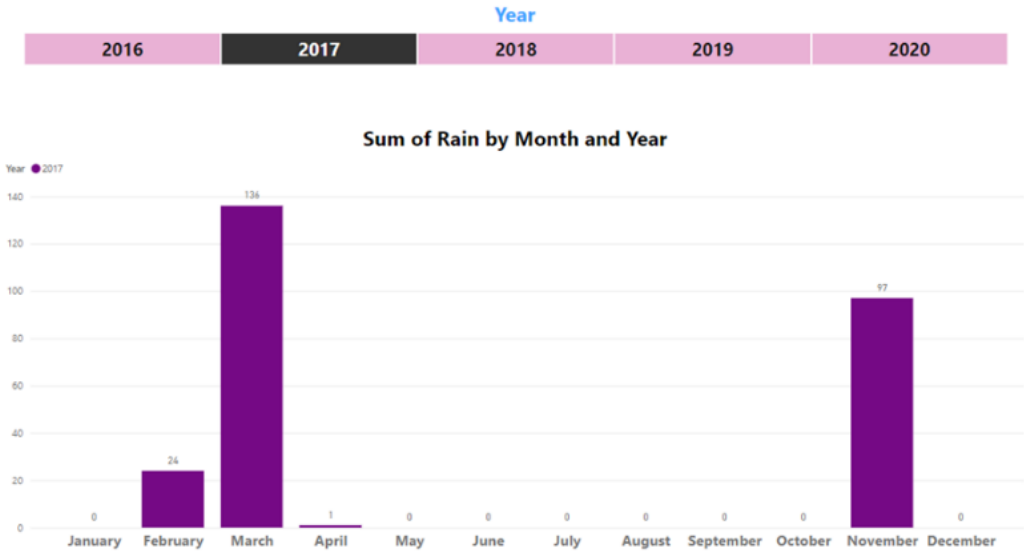

Fig. 8. Sum of Rainfall according to Month and Year.

5. CONCLUSION AND FUTURE WORKS

The proposed model-based data mart of climate changes aims to support sustainable decision-making across different sectors. Different factors of climate change are observed such as wind speed at different heights, wind direction, rainfall, temperature, solar radiation. The proposed platform will be considered as base stone for implementing DW for long-term decision making. The proposed framework provides efficient, structured, and accessible platform to analyze climate changes annually and dive in climate trends and their implications. The framework of the model shows the data mart implantation which help in decision-making process based short-term strategic decisions while the aim is to find the possibility of implementing DW accordingly. The results of implementing reports will help stakeholders to derive actionable insights. The resulting reports helps decision-makers in different fields such as policy-makers, disaster management, energy planning, and agriculture which enhance predictive capabilities, and find the correlation between factors affect climate change. To enhance the capabilities of the proposed model, may future works and enhancements can be performed such as incorporating machine learning algorithms such as decision tree, deep neural network and ensemble models for predicting patterns that affect the climate change. After collecting datasets from different locations, the spatial analysis with advance features of geographical information systems can be included for deep analysis, temporal trends, and for getting deep insights in regional and local levels. The real-time visualization will be incorporated for in-time KPIs to give real-time warning in case of dangerous climate changes.

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