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BUILDING MANAGEMENT SYSTEM FOR IOT DEVICE DATA ANALYSIS IN CLOUD AND DATA VISULISATION IN POWER BI

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Abstract : Power BI's integration with cloud services enables organizations to leverage the benefits of cloud computing for their data analytics needs. By utilizing cloud infrastructure, Power BI allows users to store and access their data securely in the cloud, eliminating the need for on-premises data storage and reducing infrastructure costs. The paper starts with accumulation of Building Management System data on to Azure cloud. Using Time series algorithm and DAX commands forecasting the future values will be done. Use of Mean Absolute Error (MAE) to calculate forecast accuracy metrics in Power BI will be used as a proof of concept.

***IndexTerms* - Power BI, DAX commands, Mean Absolute Error (MAE), Time series algorithem.**

I. INTRODUCTION

IoT (Internet of Things) device data analytics encompasses a range of techniques and methodologies that enable the processing, analysis, and interpretation of data collected from IoT devices. It involves extracting valuable insights, patterns, and correlations from the data to understand device behaviour, user preferences, environmental conditions, and other relevant factors. By analysing the data generated by IoT devices, organizations can uncover hidden trends, anomalies, and predictive patterns that can drive improvements and innovation across various domains.

One of the primary goals of IoT device data analytics is to enhance decision-making processes. By leveraging advanced analytics techniques, such as machine learning, statistical analysis, and data mining, organizations can derive actionable insights from the data. These insights enable informed decision-making, helping businesses optimize operations, improve efficiency, and deliver enhanced services to customers. For example, in the context of smart cities, IoT device data analytics can be used to optimize traffic flow, reduce energy consumption, and improve the overall quality of life for residents. [1]

IoT device data analytics also plays a pivotal role in predictive maintenance. By analysing historical data collected from IoT devices, patterns can be identified that indicate potential equipment failures or maintenance needs. Predictive maintenance enables proactive actions to be taken, reducing downtime, optimizing maintenance schedules, and minimizing costs. This proactive approach improves the reliability, performance, and longevity of IoT devices and the systems they are part of. Furthermore, IoT device data analytics enables organizations to gain a deeper understanding of customer behaviour and preferences. By analysing data generated by IoT devices, businesses can personalize offerings, tailor marketing campaigns, and provide more relevant and engaging customer experiences. This data-driven approach enhances customer satisfaction, fosters loyalty, and drives business growth.

However, IoT device data analytics also presents significant challenges. The sheer volume, velocity, and variety of IoT data pose scalability and data management issues. Additionally, ensuring data security, privacy, and compliance becomes a critical concern. Overcoming these challenges requires robust data infrastructure, advanced analytics capabilities, and appropriate governance frameworks. In today's data-driven world, visualization has become a powerful tool for understanding and communicating complex information. When combined with a cognitive framework, visualization in Power BI takes on a new dimension, enabling organizations to gain deeper insights, make informed decisions, and drive intelligent actions. [2]

Power BI is a business intelligence platform developed by Microsoft that allows users to visualize and analyse data from various sources. It provides a rich set of tools and features for creating interactive, visually appealing dashboards, reports, and data visualizations. With its intuitive interface and robust capabilities, Power BI empowers users to explore data, uncover patterns, and communicate insights effectively. Another key aspect of visualization with a cognitive framework in Power BI is the ability to detect anomalies and outliers. By applying machine learning algorithms, Power BI can automatically identify unusual patterns or unexpected data points, alerting users to potential issues that require attention. This capability is particularly valuable in areas such as fraud detection, predictive maintenance, or quality control, where the early detection of anomalies can lead to significant cost savings and improved performance. [3]

One of the key advantages of utilizing cloud services in Power BI is the ability to access data from various sources. Power BI allows users to connect to a wide range of cloud-based data sources, including databases, data warehouses, software-as-a-service (SaaS) applications, and cloud storage platforms. This seamless integration enables users to consolidate data from multiple sources and perform comprehensive analysis within a single platform. [4]

Cloud services enable seamless integration with other cloud-based tools and services. Power BI can integrate with various cloud platforms, such as Azure Data Factory, Azure Machine Learning, and Azure SQL Database, to create end-to-end analytics solutions as shown in figure 1. This integration allows organizations to leverage the full potential of their cloud ecosystem and harness the power of advanced analytics and machine learning in their data analysis workflows.

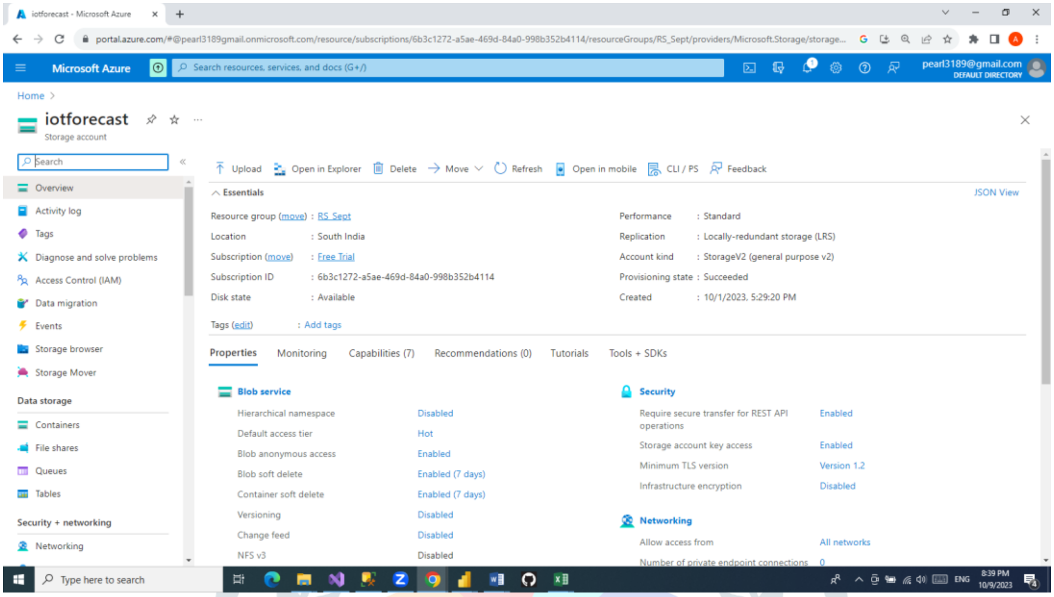

Figure 1: Default View of Azure Portal.

Furthermore, cloud services provide advanced data processing capabilities in Power BI. Cloud-based computing resources can handle complex calculations, data transformations, and aggregations efficiently, enabling organizations to perform in-depth analysis and generate valuable insights. Power BI leverages the scalability and processing power of the cloud to ensure fast and responsive data visualizations and reports, even when dealing with large datasets.

In hypothesis, the integration of cloud services in Power BI offers organizations a powerful and scalable platform for their data analytics needs. By leveraging cloud infrastructure, organizations can access diverse data sources, enable collaborative analytics, benefit from advanced data processing capabilities, enhance security, and seamlessly integrate with other cloud services. Cloud services in Power BI empower organizations to extract valuable insights from their data, make informed decisions, and drive business success in the digital age.

II. LITERATURE SURVEY

We'll explore how IoT device data analytics and visualization can be enhanced by leveraging cognitive services within Power BI and the cloud. We'll delve into the ways in which Internet of Things (IoT) devices can generate vast amounts of data and how administrations can extract actionable insights from this data using advanced analytics techniques. Additionally, we'll explore how Power BI, a powerful business intelligence tool, can be integrated with cognitive services to provide advanced visualizations and enhance decision-making capabilities. We'll also discuss the role of cloud computing in supporting these IoT analytics and visualization processes, including the benefits and challenges associated with cloud-based solutions. Overall, this topic focuses on the intersection of IoT, data analytics, visualization, cognitive services, and cloud computing, and how these technologies can work together to drive valuable insights and empower organizations in the digital era. [5]

Here are a few examples of how organizations can leverage cognitive services and Power BI for IoT data analysis:

Predictive Maintenance: Organizations can leverage cognitive services and Power BI to analyse IoT device data in real-time and predict maintenance needs. By applying machine learning algorithms and cognitive capabilities to historical sensor data, organizations can identify patterns and indicators that precede equipment failure. Power BI can then visualize these insights, enabling maintenance teams to proactively schedule maintenance activities, reduce downtime, and optimize asset performance.

Anomaly Detection: Cognitive services integrated with Power BI can help organizations detect anomalies in IoT device data. By leveraging anomaly detection algorithms, organizations can identify deviations from normal patterns or expected behaviour in real-time. Power BI can then visualize these anomalies, allowing users to investigate and take corrective actions promptly. This approach is particularly valuable in areas such as security monitoring, quality control, and environmental monitoring.

Energy Management: Cognitive services and Power BI can be combined to analyse IoT data from energy monitoring devices. By leveraging machine learning algorithms and cognitive capabilities, organizations can identify energy consumption patterns, detect inefficiencies, and suggest energy-saving measures. Power BI can then provide visualizations that highlight energy usage trends, identify areas of improvement, and track the effectiveness of energy management initiatives.

Customer Insights: By integrating cognitive services and Power BI with IoT data, organizations can gain deeper customer insights. For example, by analysing IoT device data and combining it with customer feedback or sentiment analysis, organizations can understand customer preferences, usage patterns, and satisfaction levels. Power BI can then visualize these insights, enabling marketing and sales teams to tailor their strategies, improve customer experiences, and drive customer loyalty.

Supply Chain Optimization: Cognitive services and Power BI can help organizations optimize their supply chain operations using IoT data. By analyzing data from IoT devices embedded in transportation vehicles, warehouses, or production lines, organizations can gain real-time visibility into inventory levels, track shipments, and identify bottlenecks. Power BI can then provide visualizations that enable supply chain managers to make data-driven decisions, streamline operations, and improve overall efficiency.

These examples demonstrate how organizations can leverage the combined power of cognitive services and Power BI to analyse IoT data, gain valuable insights, and drive improvements in various areas of their operations.

Implementing a cognitive IoT framework comes with various challenges that need to be addressed for successful deployment. Here are some common challenges:

1. Data Volume and Velocity: IoT devices generate massive amounts of data in real-time. Handling the high volume and velocity of data requires robust infrastructure and efficient data processing techniques to ensure timely analysis and decision-making.

2. Data Variety and Complexity: IoT data can be heterogeneous, coming from diverse sources and in various formats. Integrating and processing data from different devices and sensors, each with its own data format and structure, can be challenging. Data pre-processing and normalization techniques are needed to handle this complexity.

3. Data Quality and Reliability: IoT data may suffer from noise, missing values, outliers, and other quality issues. Ensuring data quality and reliability is crucial for accurate analysis and decision-making. Data cleansing, outlier detection, and error handling techniques are necessary to address these challenges.

4. Scalability and Resource Constraints: IoT frameworks often need to scale to handle a large number of devices and data streams. Ensuring scalability while considering the resource constraints of IoT devices, such as limited processing power, memory, and energy, is a significant challenge.

5. Security and Privacy: IoT systems are vulnerable to security threats, including data breaches, unauthorized access, and malicious attacks. Implementing robust security measures, such as data encryption, access control, and secures communication protocols, is essential to protect IoT devices and data.

6. Real-Time Processing and Latency: Some IoT applications require real-time processing and low latency response. Analysing and making decisions on time-sensitive data within strict time constraints can be challenging. Edge computing and real-time analytics techniques are often employed to address these requirements.

7. Integration and Interoperability: IoT frameworks involve multiple devices, platforms, and protocols from different vendors. Ensuring seamless integration and interoperability among various components can be complex.

8. Ethical and Legal Considerations: Cognitive IoT frameworks may handle sensitive data, raising ethical concerns regarding privacy, consent, and data usage. Compliance with data protection regulations, such as GDPR, and ensuring ethical data practices are essential considerations during implementation.

9. Robustness and Adaptability: IoT environments can be dynamic and unpredictable. The cognitive IoT framework should be robust and adaptable to handle changing conditions, device failures, network disruptions, and evolving requirements.

10. Cost and Return on Investment (ROI): Implementing a cognitive IoT framework involves significant upfront costs, including infrastructure, devices, and software development. Ensuring a positive ROI and demonstrating the value and benefits of the framework is crucial for long-term sustainability.

III. METHODOLOGY

The use of time series algorithms will be in Power BI to create a cognitive framework for data analysis and visualization. While Power BI offers capabilities for advanced analytics and modelling. You can leverage the power of DAX (Data Analysis Expressions) and the built-in analytics functions in Power BI to perform calculations, aggregations, and statistical analysis. Here's how the incorporation of time series algorithms into your cognitive framework using Power BI will work out:

Connect to Data: Import or connect to your data source in Power BI. This could be a database, Excel file, or other supported data sources.Xls Files, csv files and Data stored at Azure cloud will be taken into consideration where we can see the IoT forecast data has been stored under Azure cloud as shown in Figure 2.

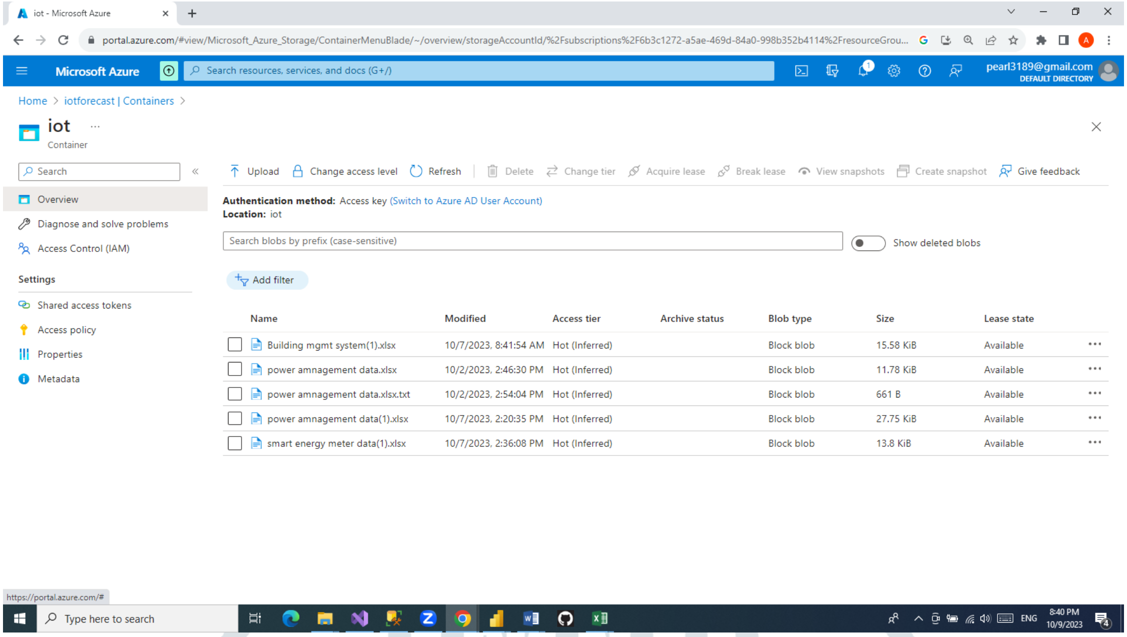

Figure 2: IoT forecast data stored under Azure cloud.

Data Preparation: Perform necessary data transformations and cleaning to prepare your data for analysis. Power BI provides a wide range of data transformation capabilities, such as filtering, grouping, merging, and calculated columns. Access keys are used for authentication and authorization purposes to interact with various Azure services and resources as shown in figure 3.

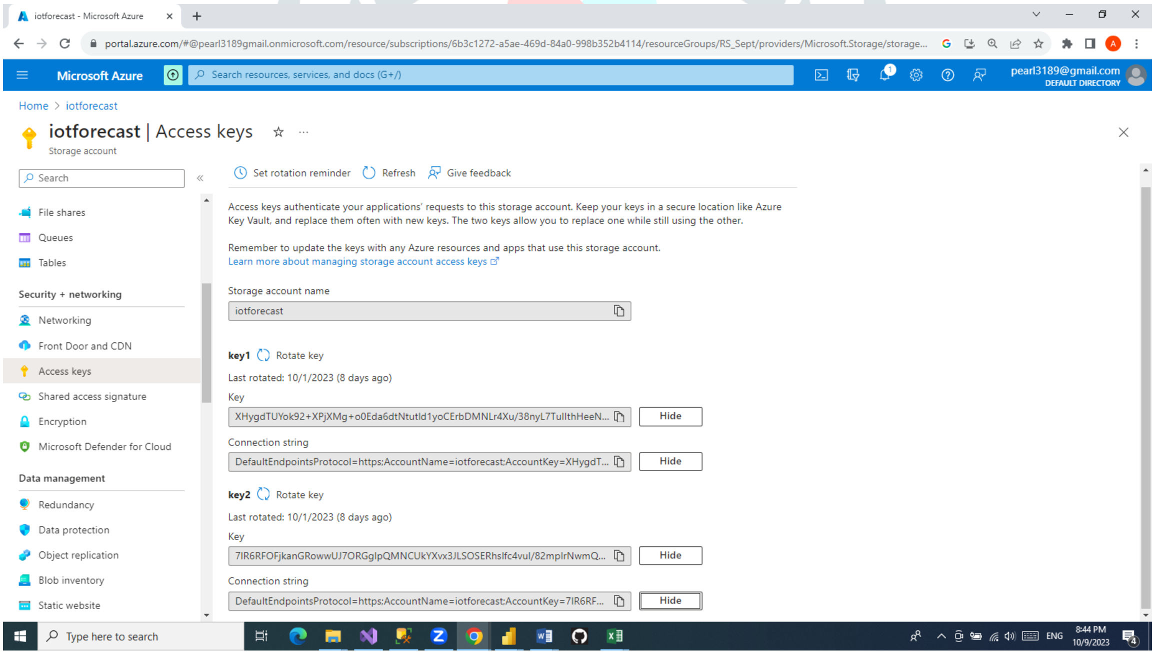

Figure 3: Access key authentication in Azure cloud.

Time Series Analysis: Utilize the built-in time intelligence functions and calculations in Power BI to perform time series analysis. You can calculate moving averages, create rolling sums, detect trends, and apply forecasting models to your time series data.
Modelling and Regression: Power BI supports statistical modelling and regression analysis. You can use DAX formulas or the R or Python integration in Power BI to perform modelling and on your data. This allows you to explore relationships between variables and make predictions based on your regression models.
Visualization: Interactive visualizations, charts, and reports to present your findings and insights have been created. Line chart visualization are shown in Power BI where first two weeks of data are extracted from csv file and corresponding forecast have been applied for next ten days.

By combining the data preparation, time series analysis, modelling, and visualization capabilities of Power BI, cognitive framework for analysing and presenting complex data patterns and trends has been created. Power BI allows you to create dynamic, interactive dashboards that enable users to explore and gain insights from your data.

IV. ANALYSIS AND RESULTS

Power BI is a powerful data analysis and visualization tool that can be enhanced with time series algorithms to create a cognitive framework for data analysis and visualization. Time series algorithms are specifically designed to analyse and forecast patterns in data over time. By integrating time series algorithms into Power BI, you can unlock advanced capabilities for understanding trends, seasonality, and forecasting future values. Here's a step-by-step guide on how the implementation has been done to use time series algorithms in Power BI to create a cognitive framework for data analysis and visualization:

Import and prepare your data: Start by importing your time series data into Power BI. Ensure that your data is properly structured with a time column and numeric values. You can connect to various data sources such as Excel, CSV files, databases, or cloud-based services. These datasets serve as valuable resources as shown in table 1. The BMS dataset acts as a foundation for research in areas such as energy efficiency, sustainable buildings, occupant behaviour analysis, and optimization of building operations.

Table 1: Building Management System (BMS) Dataset for visualisation and analysis.

Temperature	Humidity	Alert Movement(high and very high)	IR	Floor no	Date & Time	Operating Density
22.56	76	0	65	1	Mon Aug 7 06:10:25 2023	0
23.36	76	0	75	1	Mon Aug 7 07:20:25 2023	1
25	76	0	190	1	Mon Aug 7 08:33:28 2023	3
25.65	76	1	220	1	Mon Aug 7 09:25:44 2023	4
25.67	76	0	180	2	Mon Aug 7 10:26:55 2023	3
26.23	75	0	160	2	Mon Aug 7 11:40:50 2023	2
28.15	75	0	102	2	Mon Aug 7 12:10:45 2023	1
24.11	74	0	55	2	Mon Aug 7 13:37:55 2023	0
25.23	74	0	75	2	Mon Aug 7 14:26:35 2023	0
26.89	75	0	85	3	Mon Aug 7 15:44:15 2023	0
27.52	75	0	115	3	Mon Aug 7 16:15:45 2023	2
28.65	75	0	123	3	Mon Aug 7 17:18:19 2023	2
25.44	75	1	250	2	Tue Aug 8 18:35:19 2023	4
25.88	75	1	260	2	Tue Aug 8 19:35:55 2023	5
26.56	76	1	200	2	Tue Aug 8 20:27:55 2023	4
27.36	76	1	256	2	Tue Aug 8 21:15:38 2023	5
26	76	0	185	1	Tue Aug 8 22:27:59 2023	3
27.65	76	0	140	1	Tue Aug 8 23:45:49 2023	2
25.67	76	0	23	1	Tue Aug 8 00:35:29 2023	0
24.23	75	0	22	1	Tue Aug 9 01:34:49 2023	0
25.15	75	0	28	3	Tue Aug 9 02:34:29 2023	0
24.11	74	0	29	3	Tue Aug 9 03:35:29 2023	0
23.23	74	0	50	3	Tue Aug 9 04:45:29 2023	0
26.89	75	0	68	3	Tue Aug 9 05:25:59 2023	0
27.52	75	0	99	3	Tue Aug 9 06:45:09 2023	1
27.65	75	0	155	1	Wed Aug 9 08:15:11 2023	2
26.44	75	1	195	1	Wed Aug 9 09:17:21 2023	4
27.88	75	1	225	1	Wed Aug 9 10:18:19 2023	4
27.56	76	1	236	1	Wed Aug 9 11:14:51 2023	4
29.36	76	0	190	2	Wed Aug 9 12:18:21 2023	4
29	76	0	110	2	Wed Aug 9 13:45:41 2023	1
28.65	76	0	125	2	Wed Aug 9 14:17:41 2023	2
27.67	76	0	165	2	Wed Aug 9 15:19:21 2023	3
24.23	75	1	220	3	Wed Aug 9 16:16:17 2023	4
28.15	75	1	266	3	Wed Aug 9 17:13:33 2023	5
25.11	74	1	320	3	Wed Aug 9 18:24:51 2023	5

25.23	74	1	320	3	Wed Aug 9 19:25:41 2023	5
26.89	75	1	336	2	Thu Aug 10 20:40:26 2023	5
27.52	75	1	290	2	Thu Aug 10 21:40:46 2023	5
29.65	75	1	240	2	Thu Aug 10 22:41:26 2023	4
28.44	75	0	180	3	Thu Aug 10 23:42:26 2023	3

Once the data is imported, (from Azure cloud) you may need to perform data cleaning and transformation steps to ensure its quality and format. Figure 5.6 consist of two lines where blue line depicts actual power consumption on a particular day and a saffron coloured line depicts the power consumption range (as shown in figure 4) which has to considered to find the average power consumption for a particular week or set of days as and when required to forecast.

0-----very low	range	20 to 70
1---low	range	71 to 110
2---Moderate	range	111 to 160
3---Medium	range	161 to 190
4---high	range	191 to 250
5---Very High	range	251 to 400

Figure 4: Power Consumption Range to analyse W-R-B cluster.

If the operating density has a value of 3 means the power consumed for a particular time period will fall from 161 to 190 volts.

Enable the forecasting feature: The usage of time series forecasting in Power BI by leveraging its existing features like Moving Average and integrating additional tools or custom code.

Power BI provides the capability to calculate moving averages using DAX (Data Analysis Expressions) formulas. You can create a measure that calculates the average of a specified number of previous periods and use it to forecast future values. The Pseudo code for Building management system along with forecasted data is as follows

```
Calendar = var Tablez= GENERATE SERIES(DATE(2023,08,21),DATE(2023,08,31),
0.041666667) var TablezFull= SELECTCOLUMNS(Tablez,"Value",[Value],"Day",WEEKDAY([Value]),"Hour",
HOUR([Value]))
return CROSSJOIN(TablezFull,DISTINCT(DistinctHourlyConsumption[Floor]))
```

```
Calendar_HourlyForecast = UNION(SELECTCOLUMNS('iot',"DateTime",[DateTime],"DateTimeText",
[DateTime_text],"Floor",[Floorno],"IR",[IR]),SELECTCOLUMNS('Calendar',
"DateTime",[Value],"DateTimeText",[DateTime_text],"Floor",[Floor],"IR",
[forecastedConsumption]))
```

```
DistinctHourlyConsumption = DISTINCT(SELECTCOLUMNS('iot',"Day",[DayNumberofWeek],"Hour",[Hour],
"Floor",[Floor no],"Consumption",[FloorDateTime_AvgIR]))
```

For analysing the Building Management System as shown in figure 5 considers Line chart which comprises of first two weeks of data provided from table 1. The remaining set of data for next ten days will be forecasted using moving average algorithm. In the line chart data collected from IR (Infrared) Sensor is operated which calculates cumulative movement of people or any objects with in the floor that is taken into consideration. The bar chart shown below to line chart has floor wise IR Sensor data marked with different colours for different floors.

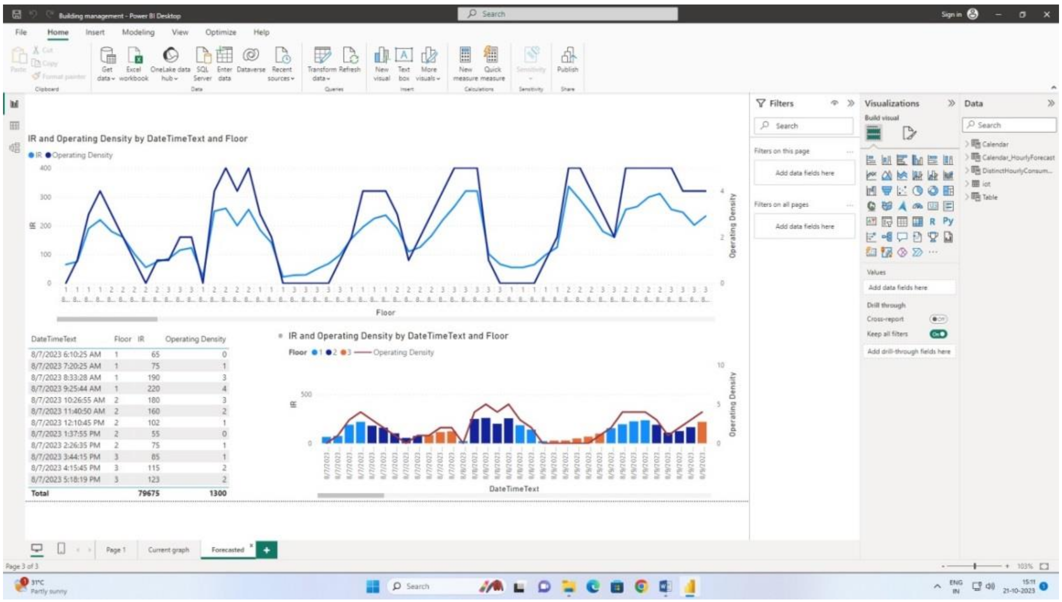

Figure 5: Consolidated Line and Bar chart for Building Management System.

Evaluate the forecast accuracy: It is essential to evaluate the accuracy of your forecasts to assess their reliability. Power BI provides measures to evaluate the accuracy of the forecasts, such as Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), or Root Mean Square Error (RMSE). These metrics help you compare the forecasted values with actual values and measure the forecast quality.

By following these steps, you can leverage time series algorithms in Power BI to create a cognitive framework for data analysis and visualization. This framework will enable you to gain valuable insights from your time series data, make informed decisions, and forecast future trends with increased accuracy. As a part of Proof of concept Mean Absolute Error (MAE) is taken into consideration. The MAE provides a measure of the average absolute difference between the forecasted values and the actual values, indicating the average forecast error magnitude. It helps you assess the accuracy of your forecasts and compare different forecasting models or parameter settings. To use the Mean Absolute Error (MAE) to calculate forecast accuracy metrics in Power BI, you can follow these steps:

Ensure you have forecasted values and actual values: Before calculating the MAE, make sure you have both the forecasted values and the corresponding actual values in your Power BI dataset. The forecasted values are generated by the forecasting algorithm in Power BI, while the actual values represent the ground truth or observed values.

Create a new measure for MAE: In Power BI, navigate to the "Modeling" tab in the Power BI ribbon and click on "New Measure." This will open the formula bar where you can define a new measure.

Write the MAE formula: In the formula bar, you can write the formula to calculate the MAE. The formula for MAE is as follows:

MAE = AVERAGEX(VALUES(Data[TimeColumn]), ABS(Data[ActualValue] - Data[ForecastedValue]))

Here, `Data` represents your dataset, `TimeColumn` is the column that contains the timestamps or time values, `ActualValue` is the column that contains the actual values and `ForecastedValue `is the column that contains the forecasted values.

Apply the measure to a visual: Once you have defined the MAE measure, you can apply it to a visual in Power BI to see the calculated value. You can add a card visual, for example, and drag the MAE measure to the "Values" field well of the visual. This will display the computed MAE value.

Format the visual and Repeat for different forecast evaluations: Format the visual to display the MAE value appropriately. You can adjust the number format, decimal places, or any other formatting options as needed. Since the considerations has been taken for Power Management, Smart Meter data and Building Management data which is taken upon multiple evaluation periods or subsets of data, you can repeat the above steps to calculate the MAE for each of them. This will allow you to compare the accuracy across different time intervals or segments. Since the absolute difference between the forecasted values and the corresponding actual values in the context of Building management System it is around 6.

Time series analysis is an iterative process. Evaluate the performance of your forecasts and make adjustments as needed. Power BI allows you to create interactive dashboards and reports to share your time series analysis findings with others. You can create visualizations that update dynamically as new data becomes available, enabling real-time monitoring and decision-making.

With the BMS on IoT devices, building owners and facility managers can gain comprehensive insights into building performance, analyze trends, and make data-informed decisions to optimize resource utilization, reduce energy waste, and ensure regulatory compliance. Moreover, remote access and control capabilities provided by IoT connectivity enable real-time monitoring and control of building systems, enhancing responsiveness and enabling timely interventions. IoT sensors will collect data related to temperature, humidity, occupancy, light levels, and other relevant parameters. This data needs to be transmitted to the BMS platform for analysis and control. Integration with cloud-based or on-premises BMS software is necessary to aggregate and process the sensor data

V. CONCLUSION

The following chapter starts with Data uploading to Azure cloud there by connecting it to Power BI for analysis and visualization. By using Time series analysis one can experiment with different algorithms, tune the model parameters, or incorporate additional data features to improve the accuracy of your forecasts.

Concluding with proof study Magnitude of error, The MAE represents the average magnitude of the forecast errors, regardless of their direction (positive or negative). A lower MAE value indicated through the results that, on average, the forecasted values are closer to the actual values, suggesting higher accuracy. Conversely, a higher MAE value indicates larger forecast errors and lower accuracy.

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