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Advanced-Data Modeling Techniques for Multi-Site Work Order Visualization in Power BI

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Abstract:
Multi-site work order displays are important and necessary when the organization has developed its operations across several sites. Power BI is one of the valuable applications for data modeling and reporting; however, working with the work order datasets across different sites is challenging. This paper aims to understand how advanced data modeling can be applied to improve multi-site work orders in Power BI. It includes key modeling techniques like star schema design, data normalization, and Power Query on the ETL process (Extract, Transform, and Load). Also, the paper covers the employment of measures to enable dynamic calculations by incorporating DAX (Data Analysis Express Expression). In this context, potential anti-patterns of low performance include complex joins, row-by-row processing, missing indexes, and repetitive execution are discussed. This paper also prescribes the best practices for Row-Level Security (RLS) to achieve secure, role-based access to work order info. Finally, the ways to utilize data streams outside the manufacturing site, like IoT devices and ERP systems, show how overall operation can be assessed. The following research combines examples extracted from real-life cases and practices to illustrate how an organization can derive value from work order data for better decision-making and business enhancement. Using all these techniques presented above under Power BI, an organization can advance its reporting capacity in facility and asset management and consequently improve its competitiveness in the market.

Keywords: Power BI, Data Modeling, Work Order Management, DAX, ETL, Star Schema, Business Intelligence.

1. INTRODUCTION

In today's complex business world, organizations operating across shifts or locations depend on work order management to manage assets, organize work, and deliver services effectively. Maintenance requests, repair tasks, and other operational workflow, which are the work orders, produce a huge amount of data that should be processed. [1-3] However, pulling and aggregating data from multiple site work orders is challenging because of the differences in data collection techniques, the reporting hierarchy, and the ability to handle large datasets.

Power BI is viewed as one of the efficient tools for business intelligence reflecting all relevant trends: interactive dashboards, real-time analytics, and possibilities of data modeling. Nevertheless, organizations must use structured data models to realize their multi-site work order visualization potential. Traditional flat-file approaches become problematic because of these coupled difficulties. They can result in slow report performance and poor capability to address complicated relationships between work orders, high levels of assets, locations, and other operations. To overcome these problems, one must use star schema architecture, optimized ETL process, and efficient use of a flowery known as DAX data analysis expressions.

This paper aims to identify how various features in Power BI can be utilized to improve multi-site work order reporting. It covers matters to do with data structuring and ways of improving its performance, including aggregations and doing an incremental refresh of data; it also describes matters to do with data security, especially Row-Level Security (RLS). Also it is proposed to extend the work to incorporate different external data sources like IoT sensor data and Enterprise Resource Planning (ERP) for having a clear view of work order efficiency. Thus, by adopting such approaches, organizations move from still picture dashboards, which were ridden by many problems, to actual time. These ever-evolving visuals give clear and separate information, which may help bring in better resources in terms of spend, maintenance, and overall operation. The main challenges related to this situation and information about data models for multi-site work order visualization, and the best practices and case studies of Power BI applications in organizations are presented in the following sections of the paper.

2. LITERATURE REVIEW

2.1. Introduction to Advanced Data Modeling in Power BI

When implemented in Power BI, advanced data modeling techniques are useful in developing reliable, sustainable, and detailed analytical leverages, especially in multi-site work order environments. In today's diverse organizations, work orders are witnessed in multiple locations, creating significant amounts of work order data that must be modeled appropriately. Standard flat-file-based or structurally flawed databases cause program slugs, data redundancy, and problems creating dynamic reports. [4-8] The following ways can help handle such challenges through advanced modeling techniques: Relationships are optimized, Query performance is improved, and Data is consistent.

Power BI's toolbox core is based on elements such as tables, relationships, and measures. The integration of these elements is structured to come up with models that can support complicated analytical needs. Thus, it is possible to use optimized schema, calculations with DAX (Data Analysis Expressions), and aggregation tools to enhance reporting capabilities as much as possible. These techniques play a role in creating more vivid visualizations and help decision-makers make informed decisions concerning multi-site work order information.

2.2. Key Advanced Data Modeling Techniques

2.2.1. Star and Snowflake Schemas

Schema design is a vital process for data organization for ease of querying and analyzing. The star schema is popular in Power BI and is based on a broad fact table with transactional data and linked dimensions describing the fact. It has the advantage of making queries easier, improving performance, and generating reports easier. The snowflake schema is an extension of the star schema in which additional normalization of the dimension tables is performed, and the dimension tables are divided into related sub-tables. On this note, the approach minimizes data redundancy but may increase the complexity of query solutions. Specifically for visualization used in multi-site work orders, a star schema is commonly used due to its relatively strong performances and acceptable complexity. Therefore, using the snowflake schema when working with a hierarchical or highly normalized ERP system is good.

2.2.2. DAX (Data Analysis Expressions) for Advanced Analytics

DAX stands for Data Analysis Expressions and is essentially an equation language in Power BI that allows users to create new calculations, provide new filtering methods, and cope with measures. Using functions such as CALCULATE, SUMX, RELATED, and FILTER, DAX is flexible and allows for creating dynamic reports and various measures. For instance, using the CALCULATE function, work orders can be restricted to certain locations, priority, or completion status in a multi-site work order environment, and this can enable the stakeholders involved to assess trends specifically established in various sites. , while, for instance, when analyzing the total maintenance costs for several sites; the major advantage of using RELATED is its ability to extract data from other related tables. It is important to note that having a good knowledge of DAX functions is crucial in developing Power BI models and providing required reports.

2.2.3. Data Relationships and Their Role in Multi-Site Analysis

Relationship between tables is one of the most basic concepts in Power BI data modeling. One is available in Power BI, including one-to-one, one-to-many, and many-to-many Relationships. However, for many-to-many relations, additional tables allowing for the association of a record from one table to multiple records from another or for composite models are needed to prevent duplicating data and maintain data integrity. For example, in developing multi-site work order visualization, one may find many-to-many relationships while associating work orders with many departments or assets. To handle these relations, the Liechtenstein ERP should, therefore, incorporate a bridge table for safe filtering and subsequent agglomeration of data to give better operative insight into the distribution of work orders across the Liechtenstein locations.

2.2.4. Calculated Tables and Columns for Custom Data Insights

Calculated tables and columns are intimately related to data operations where new data elements are computed from previously collected data sets, and data analysis. Calculated columns enable the creation of site-specific generalizations, while calculated tables let one receive summaries depending on work orders' status or priority. For instance, calculated columns may include an attribute like Response Time, which categorizes work orders as Urgent, Standard, or Delayed, which offers a snapshot view of the speed of service delivery. Also, a calculated table can accumulate the work order expenses of diversified sites for financial control and operative budgeting.

2.2.5. Aggregations for Performance Optimization

Aggregations are useful in enhancing the execution of reports since they group the detailed data to higher levels. Instead of making Power BI request millions of raw work order records, he says aggregations allow the tool to request summarized data only, saving time. For instance, while the SOP 4 transaction level is too detailed, the aggregated table may contain the total monthly work orders per site. This way, aggregations can boost the working of Power BI, especially in processing big data across organizational sites.

2.2.6. Hierarchies for Multi-Level Analysis

Organizing the 'data in hierarchies also enables drill-down functionality through which it is easy to find a piece of data down to the most detailed level.' While working with the multi-site work order visualization, it is possible to use hierarchies at the Company, Region, Site, and Department levels. This way, the specific results can be reviewed at a high level (e.g., for all the sites) and, at the same time, dig into the detailed information for individual sites or departments. For instance, an area where maintenance activity is reported can start by comparing the global work order activity and then focus on the sites where delays or high costs have been observed.

2.2.7. Role-Playing Dimensions for Contextual Analysis

Facilitated by card creation and the use of labels and keywords, it becomes possible to have a single dimension table used for several roles within the same construct. Having a Date table for the Order Date, Completion Date, and/or Scheduled Date is useful in work order analysis. Through role-playing of dimensions, the work order trends can be determined based on specific periods, thus offering an insight into how the scheduling system works, the number of pending work orders, and the completion level.

2.2.8. Composite Models for Handling Large Datasets

In Power BI, DirectQuery and Import Mode are combined into one composite model that would help the organization balance between performance and refresh rate. DirectQuery is a live connection to the databases, whereas Import Mode makes it faster to work by downloading the data. For multi-site work order reporting the composite model can be designed to import historical data and use DirectQuery for the active work order data update. It also combines efficiency in performance and reporting current standard financial reports with the usage of GAAP.

2.3. Application to Multi-Site Work Order Visualization

Implementing the application of multi-site work order visualization using advanced data modeling allows organizations to create complex work order reports that are easier to understand and interpret. This way, the work orders can be presented at different time horizons, completion trends can be evaluated, and potential bottlenecks can be identified. It also allows hierarchies to be set where a site or department-level view can be gotten out of the global level, improving the level of detail.

Integrating DAX means that calculations are performed on the spot by the programmer itself, for instance, tracking average time to complete work orders for a site by one another site that is easily achieved. Also, aggregations help maintain that large amounts of information do not overwhelm the reports while the extent of analysis is upheld. By applying such techniques, organizations can derive useful insights from work order data and utilize the information to forecast work order needs, manage various resources, and make strategic decisions. The subsequent section will focus on applying these techniques in actual business environments which will exemplify improvement to actual operational performance.

3. METHODOLOGY

This part provides an overview of the methodology implemented for creating the optimized multi-site work order visualizations in Power BI [9-13]. This carried various aspects that relate to data acquisition techniques, basic and further processing of the acquired data, and higher-level modeling techniques. These processes help create the final model optimized for interactivity, speed, and various analyses.

3.1. Data Collection and Sources

Every analytical solution starts with gathering reliable data relevant to solving the issues. The data is collected from several sources such as ERP software, CMMS, IOT devices and manual inputs from the work done in several sites. These work order systems capture important order data, such as request dates, human resources assigned, time taken, estimated cost and the assets involved.

In multi-site settings, there are issues concerning the architecture, format standard of data and system implementations of different stations for data entry. For this purpose, APIs, database connectors, and flat-file imports (CSV, Excel) are standard practices for extracting work order data. Also, in real-time IoT sensors it continues to incorporate information pertaining to various parameters of the machines for more appropriate predictions regarding its maintenance.

Confidentiality and integrity of information are very important; therefore, mastery checks are used to validate data. These checks discuss the subsets of data containing missing values, wrong date/time format, and duplicates before the data is loaded in Power BI. Once the raw data has been gathered, it goes to the preprocessing and transformation step to suit the modeling process.

3.2. Data Preprocessing and Transformation

Data acquired from various sources is in raw form and contains attributes such as missing values, duplicates, and improper formats. Preprocessing involves data cleansing and arranging of files in a proper manner which will be suitable for analysis in Power BI.

- **Data Cleaning**: This process includes addressing missing values by replacing or deleting these values, eradicating redundancy in the datasets, and converting certain formats to consistent formats, e.g., Date formatting and currency formatting. In categorical data, such as formulating propositions and creating concept maps, different sites used different names for the same thing which are standardized here.
- **Data Integration**: Since data is received from various sources such as ERP software, CMMS, and IoT, it must be combined to form one dataset. The Power Query in Power BI helps develop relations between two sources of data and the fluent connection between them.

- **Data Transformation**: The data that has been collected is then transformed into an appropriate format for analysis. This includes:
  - Splitting columns (e.g., separating date and time from timestamps for better analysis).
  - Effectively using DAX to create new columns and measures to provide further evaluation.
  - Implementing data type conversions to ensure compatibility (e.g., converting text-based numerical values to actual numeric types).

3.3. Advanced Data Modeling Techniques in Power BI

Once the data is processed, it goes through various modeling processes considered most suitable for performance and usage. Other methods include the schema design, techniques of bringing related data in specific modes of relationship and the usage of DAX in data expression of enhanced calculation.

3.3.1. Star Schema vs. Snowflake Schema

Deciding on an appropriate schema is decisive for the design of the data model in Power BI.

- **Star Schema**: Here master table includes transactional work order data, and other tables include site location detail, asset detail, employee detail, and type of work order. It also makes queries fast because the structure is simple and not complex at all. This is particularly because it is preferred for use in Power BI due to its capability to handle big data.
- **Snowflake Schema**: This is a sub-type of the specialized schema type as it continues to split the dimension tables even more into the related tables. However, it avoids repetition, making the data model more complicated in terms of queries and the resulting performance. While it's very important for highly structured ERP data, which provides the consequence of reducing the number of steps in your data flow, it also has certain limitations, and it needs more optimization to optimize the data performance.

3.3.2. Data Normalization and Denormalization

Normalization and denormalization are vital in addressing the issue of data redundancy and the issue of performance respectively.

- Normalization reduces data redundancy by organizing the data set, whereby every data element is stored only once. For instance, instead of storing site details, a Site Dimension Table is created, in which all the site's physical characteristics can be stored, which is connected to the fact table using a key.
- Denormalization should be applied in cases where performance is more important. It often entails the physical implementation of tables, which helps minimize the number of tables that need to be joined to get the needed information. For instance, instead of using tables of work order status, people involved, and time required to complete a work order, there can be just one large table to enhance reporting.

3.4. Relationship Management and DAX Expressions

Relationships between tables are critical elements of data modeling in Power BI. The structure involves many-to-one between fact and dimension tables and employs many-to-many intersection tables. [14-16] The Work Orders Fact Table is related to the Sites Dimension Table, a one-to-many relationship. At the same time, a bridge table is responsible for the many-to-many relationship between assets and maintenance personnel. Cross-filtering, which occurs between two tables, is made selectively to and on and used comprehensively to avoid causing a headache to the system by slowing down its performance.

For advanced analysis of the data, calculation of new measures, and calculation of the new columns DAX language (Data Analysis Express Expressions) is used. Some key DAX applications include:

- **CALCULATE**: Used for filtering and modifying context-based aggregations. Example:

Total_Work_Orders = CALCULATE(COUNT('Work Orders'[Order ID]), 'Work Orders'[Status] = "Completed")

This measure counts the number of completed work orders.

- **SUMX**: Applied for row-by-row calculations, such as total work order costs:

Total_Cost = SUMX('Work Orders', 'Work Orders'[Labor Cost] + 'Work Orders'[Material Cost])

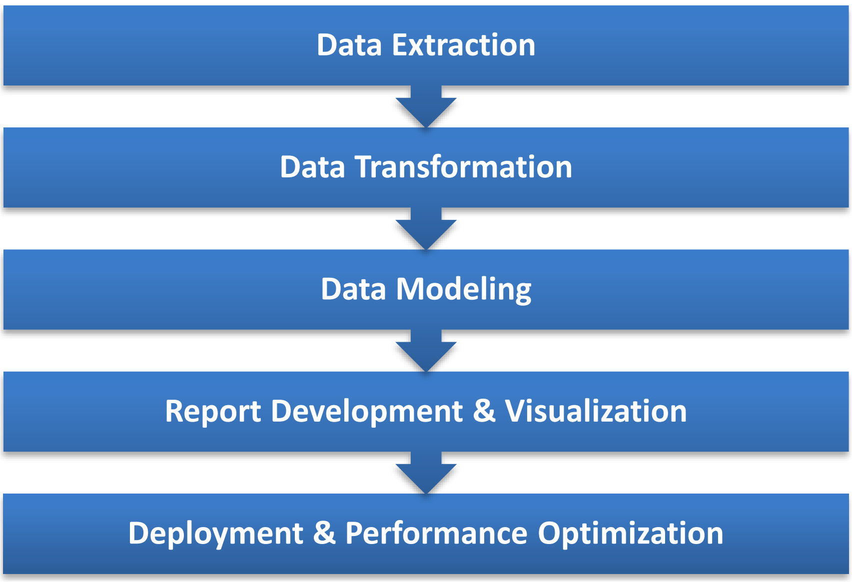
- **RELATED**: Retrieves values from related tables, such as fetching site details for a specific work order:

Site_Name = RELATED('Sites'[Site Name])

3.4. Implementation Workflow

The implementation workflow can be described as a step-by-step plan detailing all activities that must be undertaken to design and deploy the Power BI resolution to help visualize the multi-site work order system. This workflow helps the data be easily extracted, transformed, modeled, and visualized to make meaningful conclusions for the practical running of organizations. It comprises five steps: Data Extraction & Cleaning, Data Analysis, Model Building, Report Writing, and Deployment & Fine-tuning. All the stages are important to ensure that information continues to be precise, retrievable, and usable for computing.

Figure 1: Implementation Workflow



Step 1: Data Extraction

The initial action with work order information requires extracting data from various materials to get to the entire view of all the details involved in a work order. These may include ERP systems, CMMS, IoT sensors, SCADA systems, Excel and CSV files, Azure SQL, Google BigQuery, AWS Redshift, and others. It allows us to collect data from various sources and provides key information about the work orders in different facilities.

Power BI Data Connectors are employed to directly link to a database, ERP Business API or cloud for efficient data extraction in real-time. There is a method called incremental refresh; it is used when dealing with large volumes of data because it only updates records in the system that are not already contained. Moreover, data updates are programmed consistently to run on a schedule to create real-time figures for the operational reports.

Step 2: Data Transformation

Power Query is next applied to the raw data, where preprocessing and transformation occur. They found it important to perform this step to clean the data, resolve all the inconsistencies, and make the data consumable before getting into Power BI. Some tasks include cleaning the data (removing duplicate rows, handling null values), integrating multiple sources so they must be combined into one table data formatting, and formatting currency and measures units.

DAX (Data Analysis Expresses) is used to build calculated measures that provide useful information such as successful work order rate, average time to resolve, and cost analysis. Raw-Level-Security (RLS) is implemented in Power BI, whereby only authorized personnel, such as the regional managers for a given region, are provided access to that region's data. Additionally, it builds the use of parameterized queries due to optimizing SQL-based transforms, ameliorating query speed, and minimizing computer overhead.

Step 3: Data Modeling

Information after transformation is arranged in a manner that organizes data to enable easier query and/or generation of required graphics. Probably the most efficient method is to utilize the star schema approach when establishing a Work Orders Fact Table in relation to dimension tables like Sites, Assets, Employees, Work Order Types, and Time Periods. This model improves query by retrieval in a computation and makes it easier to acquire data.

In order to accommodate intricate relationships, role-playing dimensions are employed, meaning that a single Date Table can host many date fields, including the Order Date Field, Completion Date Field, and Scheduled Date Field. Also, many entities are related to using bridge tables to ensure the representation of accurate information of the many entities involved. New tables for aggregated data and work order levels (e.g., site level) are also incorporated through site work order counts to lessen the number of queries required to generate reports and increase the report's response time. In order to accomplish it, the final data model is developed in Power BI Model View setting cardinality and relationship to perform better.

Step 4: Report Development & Visualization

After establishing the data model, the next thing is to create end-user applications that facilitate real-time visualization of work order performance. In Power BI, it is possible to choose from several ways to present data and make the users interact with the data. Drill-down, such as hierarchical, enables users to switch from a company-wide view to a regional and site view. Electronic dynamic filters and slicers help to sort the work orders by status (Pending, In Progress, Completed), priority level, person assigned to the work order, or type of asset.

Maps and other geographical representations are used for the distribution of the work orders at different sites, as well as for understanding operational patterns and possible delays. The work order KPI cards and trend analysis of graphs cover components that may include average work order completion time, backlog count, and technician efficiency. The values of the DAX expressions are also used to define calculated measures, which include average work orders and total work orders by site. Hence, tooltips, drill-through pages, and bookmarks enrich and empower the experience of using DHTML to work with reports.

Step 5: Deployment & Performance Optimization

After it has been developed, the report is published to Power BI Service to make it live and accessible to all folks in the business. This comprises sharing the report to Power BI Service, setting the schedule for the data to be refreshed and controlling the amount of data a user can view with the help of PowerShell script using RLS.

To optimize its capacity, aggregation techniques are applied to compute pre-aggregate tables before they are queried on very large datasets. The incremental refreshing technique updates only those newly added records to the work orders; hence, the review time will be reduced. To minimize dynamic probing overhead, DAX includes variable measures and pre-aggregate values. Furthermore, the options to optimize the model size include deemed useless column deletion, efficient relations, increased report response time, and the guarantee that even large dashboards remain reactive.

4. SYSTEM ARCHITECTURE AND DESIGN

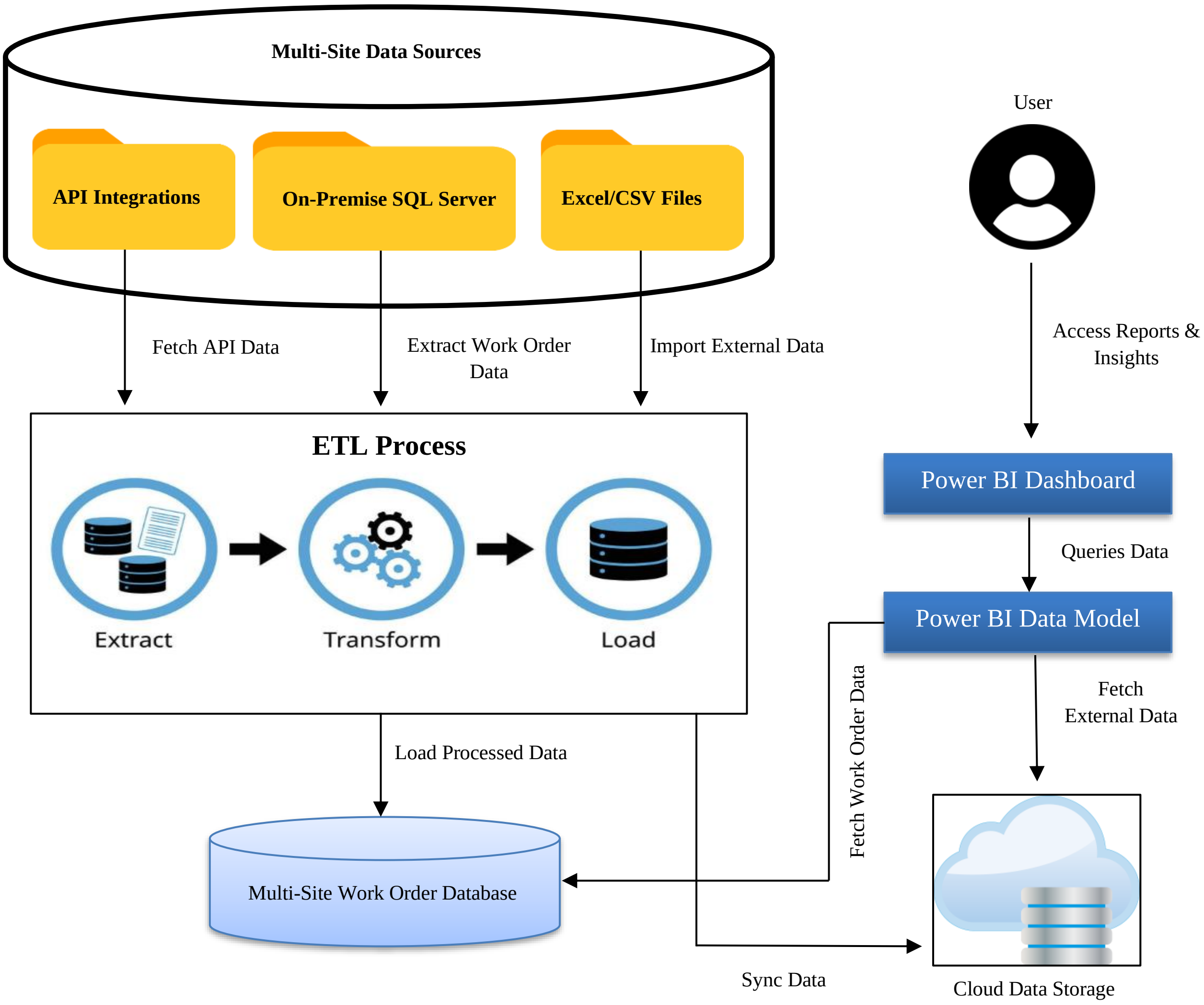


Figure 2: Multi-Site Work Order Visualization Architecture in Power BI

Multi-site work order visualization Power BI data flow presenting the system architecture and data flow of Power BI at multiple sites before reaching the dashboard. It also shows how integrated APIs, on-premise SQL servers and Excel or CSV files help to make the reporting system. This conforms to an architectural plan where data is extracted, transformed, and loaded (ETL) and entered into the work order database. Using this power fertilizes the essence of Power BI: data modeling and visualization.

The ETL Process (Extract, Transform, and Load) is at the center of this IAM model. Raw data is processed to correct inconsistencies, standardize formats, and optimize the data before storing it in the Multi-Site Work Order Database. It demonstrates how the different streams feed into Power BI and how they are coordinated to ensure it can query and analyze the data. The work order data is then structured and transmitted to the Power BI's data model after which it connects to external cloud data storage. This makes it possible for Power BI to use real-time and historical work orders from different sites.

Once the data is loaded and optimized in Power BI's data model, it easily becomes ready for analysis and representation on the various reports. Specifically, the Power BI Dashboard helps the user navigate the work order data, filter the data with the desired parameters, and analyze the key trends, operation performance, and efficiency measures. This image can be viewed as the final vision of the end-users to obtain the reports and insights to show how Power BI is an easy-to-use tool for decision-making. Through the formulation of data flow in this way, the various organizations shall be able to integrate data well, improve the accuracy of their reports, and increase the visibility of their operations in more than one location. It has features such as trend analysis, KPI, and drill-down to help the managers notice inefficiencies in work order management and how to improve them properly.

5. IMPLEMENTATION AND CASE STUDY

5.1. Implementation of Advanced Data Modeling Techniques

Multi-site work order visualization with the help of Power BI using the changed data modeling technique is possible by following clear steps. The first step is creating an efficient data model, which can be a star or snowflake structure. Star schema is one of the simplest models, which contains a center fact table surrounded by many dimension tables. But a snowflake schema takes arranging of dimension tables, further eliminating redundancy, which may again result in more joining, distorting the efficiency of queries. These schemas ensure that the data collected can be partitioned to be easily filtered or summarized based on attributes like site location, department, or time.

Excel is DAX (Data Analysis Expressions); it enables the formation of further complex calculations, consolidation, and even time intelligence. Through the use of some DAX functions such as CALCULATE, SUMX, FILTER, and RELATED, an organization can be able to analyze multi-site work orders. These functions allow businesses to ensure a work order completion rate, the average time to resolve a work order, and track change over time. Also, models that use DirectQuery and Import modes allow for querying large tables and optimizing data loading to maintain good performance.

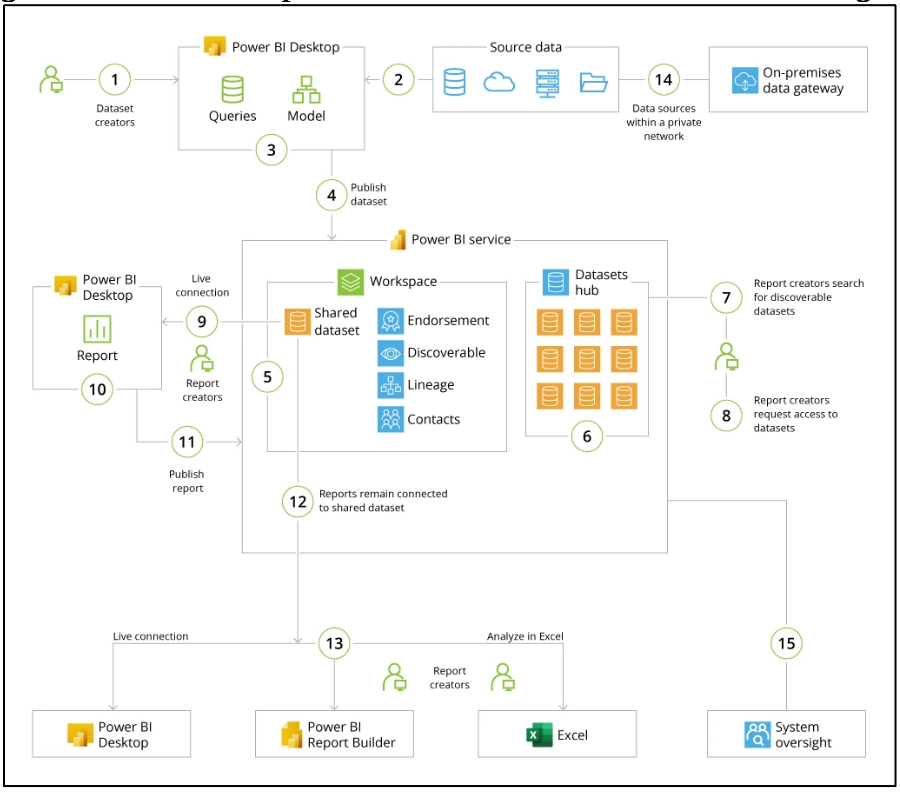
5.2. Case Study: Multi-Site Work Order Visualization

These techniques let us consider a large manufacturing firm in varied regions. One issue the company experienced was that they could not easily track work orders in different sites, making it difficult to assign the right quantity of resources and plan maintenance. To solve this, they adopted the star schema where the fact table was work orders with supporting dimension tables of site location, departments, work order type, and periods.

Power BI dashboards also let users navigate from the aggregated view of work orders to a specific facility. More specifically, the use of further developed DAX functions proved helpful in calculating important indicators such as the percentage of completed work orders, average time for resolution, and open maintenance tasks by site. It implies that by presenting these KPIs in Power BI reports, the various stakeholders could discover some of the areas of concerns or needs that require its attention while improving on their working plans.

Multiple data sources from ERP systems, maintenance logs, and real-time sensor data were combined into a single information model in Power BI. This made it possible for system updates to be done automatically and informed key stakeholders of the updated information. The implementation ensured that operations were enhanced to increase efficiency, provided the best schedule to check on the devices before they developed issues, and greatly decreased the downtime in the various sites. In the specific case scenarios of workflow, the make-up of datasets, reports, and dashboards inherent to using Power BI. It illustrated the data ingestion process from the different data sources to the Power BI and made an understanding to the users or the creators of the datasets; the Power BI report creators, and the managers who oversee the system.

Figure 3: Power BI Implementation Workflow for Dataset Management



The Power BI Desktop is the tool data creators use for querying and modeling the data before it is published to the Power BI Services. The published dataset is kept in a common area for its accessibility, advisement, and utility to other and different report writers. Data sets are centralized and managed from a single location to be searched easily by the users, and access can then be requested. [17] It also allows for governing data sharing, yet maintaining a regulated way of access to the data.

The live connection feature enables the reports in Power BI Desktop, Power BI Report Builder, and Excel to remain reliant on a shared dataset. This means that all the reports base their information on the most up-to-date data available without retrieving it from another source. Also, the on-premises data gateway is shown as connecting to the private network data source and enables secure data procurement without manually uploading the data to the cloud. Independent data source models of Power BI help improve the system's collaboration, growth, and management. Suppose the data items are structured in a centralized location. In that case, it will be easier for the organization to manage its data. Simultaneously, organizations can avoid replicating data and make their reports more efficient when dealing with multiple report makers and analysts. This fits well with the methodology of work order analytical modeling at multiple-site facilities, which enables real-time results to enhance the efficiency of operational activities.

5.3. Benefits and Outcomes

The use of enhanced techniques in data modeling in Power BI was beneficial across many aspects of the organization. First, it improved the formal objectivity of reports by standardizing the reporting style across all the different locations. Second, it enhanced queries and made them faster, and many of the dashboards are much more interactive and engaging. [18-20] Thirdly, the functionality for user interactivity was greatly expanded, including dynamic filtering, drilling down into different levels of data, as well as performing predictive analytical methodologies. Using composite models combined with optimized DAX calculations would ensure the organization could easily analyze past and arriving work orders to make accurate decisions about the costs incurred. Interpreting the work orders at the organization's global, regional, and functional levels helped the managers make intelligent decisions independently. That led to a decrease in the work orders backlog, shortening of response time and proper distribution of the resources. Finally, some enhancements decreased operational costs and increased Overall Equipment Effectiveness (OEE) at various facilities.

6. EXPERIMENTAL RESULTS

An experiment was performed to assess the performance of advanced data modeling techniques in Power BI to visualize the multiple-site work order data for a manufacturing company dataset. They have several facilities and have lost track of all the work orders; thus, they chose to implement this solution. Specific details captured in the dataset completed for this experiment included site IDs, work orders, their status, the completion date, and the maintenance type. The project aimed to apply Power BI features such as a star schema, DAX calculation, and interactive features to better analyze the data, improve decision-making, and increase operational effectiveness.

6.1. Data Preparation

Organized data treatment and approach towards data analysis. In order to organize the data for an optimum analytical query, this dataset was converted to a star schema, which is commonly utilized for improving its performance. This facility was designed based on a star schema with a fact table made from the work order records and dimension tables focusing on the site locations, departments, and time frames. Data Analysis Expressions, abbreviated as DAX, was used to develop dynamic measures that enabled the work order data of Formula One across various locations to be summed up. These measures allowed us to identify key factors such as completion rates of the tasks, average time of their resolution, and specific tendencies on site, so it was possible to receive functional recommendations regarding work efficiency.

6.2. Visualization and Analysis

Creating maps, bar charts, and key performance indicators was employed to create interactive information visuals for further analysis using Power BI. These dashboards enable users to move from a top organizational level to a specific site-level approach. Using these visual tools, managers could work on analyzing work orders according to regions, sites, and departments, facilitating a more detailed look at operations. The dynamic filtering of data that allows seeing the same data set in different aspects was another aspect that improved the tool's usability for data analysis and decision-making.

6.3. Results

The experimental outcome highlighted increased report performance and interaction among the users. The essence is that the query and reporting took less time when using the structured approach with optimized data models. Also, users could perform work order analysis at many levels as it allowed them to look from a broader perspective and see certain issues that might need improvement. The experience allows for improved attention to the sites and departments' performance, the distribution of resources more efficiently, and time spent on work to be optimized.

The data analysis shed more light on the general performance aspects. In Table 1 herein, work order completion rates by site have been provided, and they reflected a 90% completion, an aspect that proved that the operations were efficient. Table 2 shows the average resolution times by department, meaning there exist differences in efficiency levels across the departments. For instance, the maintenance department took an average of 3 days to close such issues, while the operation department took 5 days. These included areas that called for process improvement, especially in minimizing the time taken to complete maintenance and operation of the machines.

Table 1: Work Order Completion Rates by Site

Site Location	Total Work Orders	Completed Work Orders	Completion Rate
Site A	500	450	90%
Site B	600	540	90%
Site C	700	630	90%

Table 2: Average Resolution Times by Department

Department	Average Resolution Time (Days)
Maintenance	3
Operations	5
Quality Control	2

Experimental findings indicate that the work order visualization across multiple sites can be done efficiently with the help of advanced data modeling tools in Power BI. Dynamic management of Star schema structures, advanced calculations utilizing the DAX language, and the use of composite models facilitated accurate reporting, faster query time, and better utilization from the users. With data being stored in various physical and virtual spaces such as on-premises databases, cloud storage spaces, and ERPs, organizations can integrate the databases to get a more comprehensive view of operations.

The specifics revealed during the analysis are strategic, operational insights that regular reporting cannot achieve. On this aspect alone, there is an indication that various departments differed in efficiency, especially based on the resolution times recorded from each site. This insight underlines the requirement of organizational development in other aspects like maintenance schedules and overall working mechanisms. As such, through the help of Power BI's dynamic reporting tools, the decision-makers can effectively seek to address these areas and make necessary changes to reduce costs and increase efficiency in those processes.

7. CHALLENGES AND LIMITATIONS

7.1. Data Integration Complexity

Data aggregation is complex when it involves data from various sources, such as an on-premises database, cloud hosting, API, and Excel, in the context of a work order spread across multiple sites. It increases the data quality problems, and preprocessing becomes necessary due to differences in data formats, update frequencies, etc. It's critical that when integrating multiple systems, there is some way to ensure that several misalignments are addressed through ETL processes and data governance on an ongoing basis.

7.2. Performance Optimization and Scalability

Since the data is large and volume increases, query and report generation time matters greatly. If a user deals with many records, which reach millions, it can bring some issues to performance even if using DirectQuery mode to provide real-time data. Understanding how to plan and design your data models properly and the best practices of utilizing aggregations and proper indexing along with DAX expressions will allow for the most efficient and fast data processing for the end-users in the context of dashboards. Thus, the problem of sharing import and DirectQuery modes into one is crucial for performance and data availability.

7.3. Security and Access Control

Managing multiple sites poses some limitations in data protection, particularly operational and financial data. RLS should be applied because it enables limiting some records based on the role of users and the site they belong to. User management, including permission handling and following some regulations such as (GDPR) or company policies on IT, makes the deployment more complex. To avoid such problems, user authentication and data encryption are important.

7.4. Learning Curve and Adoption

DAX calculations, composite models, explicit relationships, and other techniques exist beyond basic Power BI knowledge and may not be easy to implement. Developing employees to comprehend data models, construct sensible information from the model, and fine-tune the queries may also require time. Also, thus, reluctance to implement new reporting tools can become a barrier to effective decision-making. Education sessions should be conducted continually, and a clean and efficient-looking Power BI dashboard should be adopted to receive high uptake for more use and thus improve the benefits that can be obtained from the system.

8. FUTURE WORK

8.1. Enhancing Real-Time Data Processing

Many areas of further research can be implemented in the future; the first one is to enhance the real-time linkage of data in multiple sites within the work order visual presentation. Using streaming datasets and real-time streaming options in Azure Synapse Analytics or from Microsoft Power BI could assist organizations in real-time work order changes. Thus, avoiding hasty decision-making and time-consuming solving of maintenance and resource issues would be possible.

8.2. Incorporating AI and Machine Learning for Predictive Insights

Power BI implementation of AI and machine learning models would improve the forecasting aspect of work order analytics. Through analyzing historical patterns, other techniques like predictive modeling could be used to estimate the failure of equipment, the timing of maintenance, and the time taken to address the work orders. The problem with applying AI in measuring actual performance is that Power BI does not yet have AI capabilities built into the application's visuals; thus, combining with Azure Machine Learning could add additional value to improving operational efficiency.

8.3. Expanding Cross-Platform and Mobile Accessibility

Thus, as a number of organizations adopt remote and mobile working situations, it is vital to have mobile-first access to Power BI dashboards. We may look at improving the dashboard's functionality and ability to provide data even offline and using Power BI, especially in mobile applications. This would enable the site managers and technicians to view work order reports from their smartphones or tabs at the working sites, enhancing their decisions.

8.4. Automating Data Governance and Compliance

As new data security policies continue to be established, there is a need to introduce automation of policies in Power BI. Further research can be performed on the topic of automatic data classification, its sensitivity labeling as well as compliance checking in Power BI. Concerning the LA site, certain changes would improve the security status and meet the growing needs of the company: the implementation of AI-based anomaly detection concerning unauthorized data access and the installation of automated auditing tools.

9. CONCLUSION

This paper also showed how using advanced data modeling in Power BI for multi-site work order data can enhance the understanding ability of business intelligence, particularly integration analysis and decision-making. Using star and snowflake schemas, DAX expressions, composite models, and role-playing dimensions can greatly help organizations wishing to improve their reporting performance. The case study's findings included a general increase in the ease of access to data, better query response time, and the ability to engage users to facilitate improved insights into the operational performance of different sites.

The data integration process, performance concerns, security questions, and solution acceptance provide challenges in the context. In the future, it will be helpful to focus on live data connection, artificial intelligence predictive analysis, mobile interface and options, and automatic data management to improve Power BI. When such data models are adjusted and continuously improved and when the latest or new technologies are incorporated, organizations can optimize many aspects of operations, allocation of resources, and decision-making, especially in large organizations with multiple sites.

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