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Enhancing operational efficiency with business intelligence: Industrial applications

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ABSTRACT

In the rapidly evolving world of business intelligence (BI) and data analytics, Microsoft Power BI Desktop has become a key tool for data visualization and improving decision-making across various sectors. This article examines the development of Power BI Desktop since its introduction in 2017 and provides a detailed analysis of its applications across different industries, with a focus on manufacturing. The aim was to create an analytical tool that would meet the specific requirements of a company facing challenges in efficiently processing and visualizing large amounts of data. As part of this research, we developed a dashboard in collaboration with a manufacturing company, designed according to its needs. In the process of selecting the tool, we compared Power BI Desktop with other popular tools such as Tableau and Qlik Sense. We found that Power BI Desktop best suited the company's needs, especially in terms of cost-effectiveness, ease of integration with existing systems, and the ability to customize visualizations for different organizational needs. This tool provided valuable analytical insights that helped identify areas for improvement, such as optimizing manufacturing processes and reducing downtime. The results show how the use of Power BI Desktop led to significant improvements in operational efficiency and supported strategic decision-making. This paper contributes to the literature on practical applications of Power BI Desktop in real business conditions, providing concrete examples and recommendations for further use of this tool in various industrial sectors.

Keywords: data visualization, business intelligence, power BI desktop, dashboard development.

INTRODUCTION

Currently, the importance of data visualization and business intelligence (BI) tools is growing in all sectors where effective analysis of large data volumes and support for decision-making processes are essential [1]. This article focuses on the practical use of Microsoft Power BI Desktop in a manufacturing company environment and compares it with other tools such as Tableau and Qlik Sense to demonstrate its efficiency and suitability for the company's needs. In 2017, Power BI Desktop was recognized as a pivotal tool in business intelligence and data analysis for its robust capabilities in generating visually engaging reports and dashboards from diverse data sources, offering a unified and comprehensible presentation. Its proficiency in converting raw data into interactive, visually pleasing formats was essential for informed decision-making and delivering insights to varied audiences. This period highlighted Power BI Desktop's versatility and alignment with contemporary data visualization needs, facilitating data analysis and presentation across multiple platforms, affirming its esteemed role in the business intelligence and data analytics domain [2]. Building on Power BI Desktop's established importance in business intelligence, "Pro Power BI Architecture" reinforces its indispensability for data visualization and analysis. The book delves into Power BI Desktop's central role in formulating and executing Power BI Desktop strategies, offering detailed examples and methods for managing and protecting Power BI Desktop assets. It also covers the creation of shareable analyses and the security protocols vital for Power BI Desktop's efficacy. Thus, Power BI

Desktop is portrayed not just as a visualization tool but as a key component in Power BI Desktop's architecture and operational framework, emphasizing its influence on business intelligence methodologies. This seamlessly connects to its recognized value in 2017, showcasing its evolving impact and utility [3]. A 2019 article demonstrates the use of Power BI Desktop to enhance the evaluation of educational programs through visualization. Power BI Desktop is presented as a key tool in business intelligence, simplifying data processing and analysis and enabling clear visual presentations. This highlights the versatility and importance of Power BI Desktop in decision-making processes and data analysis [4-5]. F

Following the trajectory of Power BI Desktop's evolution, the "Pro Power BI Desktop" book builds upon its foundation, showcasing its advanced development focused on enriching data storytelling and interactive narratives across devices. This progression from its recognition in 2017 as a critical tool for business intelligence and data analysis to its sophisticated applications in 2019 for educational program evaluation exemplifies Power BI Desktop's expanding capabilities. The book emphasizes the tool's role in not only enhancing data visualization and analysis but also in adapting to the dynamic requirements of data communication, thereby extending Power BI Desktop's utility and reinforcing its pivotal position in the domain of business intelligence and data analytics [6–7].

Extending Power BI Desktop's capabilities, the book offers insights into leveraging artificial intelligence features to enhance data analytics. It provides practical examples of utilizing AI functionalities, accessible through clicks or coding in languages like R and Python, enabling users to gain deeper insights and integrate statistical analyses into their Power BI Desktop projects. This progression showcases Power BI Desktop's adaptability to incorporate advanced AI features, catering to users eager to elevate their analytical endeavors [8]. In 2020, Power BI Desktop extends into environmental health, with its ability to generate multi-panel dashboards for air quality analysis showcasing its adaptability in processing and visualizing complex environmental data. This functionality emphasizes Power BI Desktop as a versatile tool that supports experts in acquiring key insights and efficiently conveying results [9–11]. In 2021, the development of Power BI Desktop highlights its versatility, including the newly added capability of sharing information and visualizations on mobile devices, expanding its usage [12]. Continuing the trend of innovations in 2021, Power BI Desktop distinguished itself with the ability to create and apply thematic files and JSON (JavaScript Object Notation) specifications for dashboard customization. This feature provides users with greater control over the visual aspect of their analyses, underscoring the flexibility and user-friendliness of Power BI Desktop as a business intelligence tool [13].

During the COVID-19 pandemic, Power BI Desktop proved pivotal in creating healthcare dashboards, as demonstrated by a 2019 study on an emergency department in Iran. The study, employing a user-centered design approach, highlighted Power BI Desktop's versatility in handling complex data, showcasing its vital role in business intelligence and data analysis solutions tailored to specific challenges. Development, Implementation, and User Evaluation of COVID-19 Dashboard in a [14]. The expansion of Power BI Desktop into scientific research for creating a researchers' ranking in 2022 demonstrates its progress as a tool for addressing diverse analytical challenges. This study highlights Power BI Desktop's flexibility in processing and visualizing complex data, confirming its growing significance not only in business intelligence but also in scientific inquiry. [15]. In 2022, Power BI Desktop continues to strengthen its position in environmental research, this time applied to waste management analysis, expanding its usage from 2020 and showcasing its ongoing development and adaptability in addressing complex environmental challenges. This progress is further validated by another study from the same year, highlighting its capability in sophisticated data analysis within environmental health sectors [16–18]. In the same vein, 2022 also witnessed Power BI Desktop's foray into the educational sphere, specifically in data science and engineering, enhancing students' entrepreneurial thinking and problem-solving skills through data analysis and visualization. This extension of Power BI Desktop's application beyond business contexts into academia underscores its versatility and growing relevance in diverse fields [19]. This adaptability of Power BI Desktop is further demonstrated in its integration with cloud technologies and R programming for health analysis, expanding its applications within the educational sector [20]. This adaptability is further enhanced in 2022 with the integration of Charticulator into Power BI Desktop, enabling users to create advanced, customized visualizations. This broadens the software's utility in data presentation and pushes the boundaries of its standard visual capabilities [21].

In 2023, the application of Power BI Desktop extends into the realm of renewable energy management, exemplifying its utility in evaluating and optimizing energy solutions through a case study on microgrid systems. This further showcases Power BI Desktop's evolving role in sustainable and environmental research, highlighting its capacity to integrate and analyze complex data sets for impactful decision-making [22]. In the same year, Power BI Desktop penetrates the A/E/C/FM sectors, supports the conversion of BIM into digital twins, and emphasizes its significance in digital transformation and sustainability [23–24]. Even in 2023, Power BI Desktop was effectively utilized in the environmental sector, this time for analyzing biodiesel production processes in Brazil, reaffirming its ongoing contribution to addressing ecological challenges [25–26]. Power BI Desktop showcases its adaptability in social and healthcare sectors by analyzing the phenomenon of chemsex, further expanding its application boundaries within public health [27–28]. In 2024, Power BI Desktop extends its application not only in healthcare, supporting legislative analysis, but also in the academic field, where it simplifies the processing of unstructured data. This progress highlights its adaptability and versatility across various sectors, underscoring its role in digitization and enhancing decision-making processes [29–30].

For this study, Power BI Desktop was selected mainly for its ability to handle large datasets and provide advanced visualization and analytical tools, which were necessary to meet the manufacturing company's requirements. Other tools, such as Excel, did not offer sufficient robustness to handle the project.

The final part of the article will compare Power BI Desktop with alternative solutions such as Tableau and Qlik Sense to provide a broader context and confirm its effectiveness. Further research steps, based on the company's requirements, will also be presented, focusing on process optimization through data visualization.

MATERIALS AND METHODS

In this study, our objective was to collaborate with a small manufacturing company, which wished to remain anonymous, and develop a dashboard to monitor the utilization of their machinery. The firm approached us with the request to create a tool that would provide a better overview of the efficiency of their machine resources. The goal was to provide the company with a tool that could be used continuously, with the ability to update and expand with new data and machinery in the future, such as for the year 2024. The dashboard was designed to be intuitive and easily adaptable to various operational needs while maintaining the privacy and desire of the client to keep the company's identity confidential. The development and implementation of the dashboard involved close collaboration with the company to understand their specific needs and work processes. An iterative approach was utilized during the development, regularly reviewing the design with end-users, and incorporating their feedback. Emphasis was placed on the system's ability to adapt to the changing requirements of the manufacturing environment, as well as its capacity to extend functionality with the integration of new machines into the production process.

Detailed documentation of data collection methods, software development, and testing is provided not only as a quality assurance for our collaborating firm but also as a resource for potential future replication and validation of our research by other parties interested in the field of industrial analytics and production management.

Procedure for creating the requested dashboard

In this section, we provide a detailed account of the steps we took in creating a specialized dashboard for our collaborating company. To this end, we developed our own process map, which served as a methodological guide, ensuring a systematic approach to the dashboard's development while allowing for effective feedback and iterations as needed.

The process map we created is critical for organizing and documenting the progression from the initial design to the final implementation stages. It encompasses all essential steps, such as data import, cleansing, transformation, modeling, and up to the creation and customization of visualizations, which form the foundation for data analysis and interpretation. Each step was designed to maximize the relevance and readability of the data for the dashboard's end-users.

The following Figure 1 illustrates this creation process. This image is not merely illustrative but represents the process we developed based on the company's requirements. It serves as a visual guide to understanding the procedure and provides a foundation for the reproducibility of this approach within the company or its application in similar projects.

The first step, "START," encompasses orienting ourselves toward a comprehensive understanding of the collaborating firm's specific data monitoring and analysis needs. This phase included in-depth dialogues with the company to collect details on the particular data types they aimed to track and scrutinize. Predominantly, the data managed by the firm was stored in formats compatible with Excel, enabling us to refine and optimize these files for an efficient import into Power BI Desktop. This preparatory work was pivotal to ensure seamless data integration into the analytics tool and was a critical component of the planning stage since well-structured and ready data files are the foundation for successful analysis.

The second step, "Data Import," involved not just the process of importing data files into Power BI Desktop but also an initial data check that was automatically conducted in Power Query upon data insertion. This process allowed for a quick and efficient review of individual data columns, ensuring their correct structure and quality before further analysis.

During this check, key data attributes such as column names, data types, and initial values were identified and examined, enabling us to immediately detect and address any apparent discrepancies or errors in the data. This step was crucial to ensure that all data were correctly imported and prepared for subsequent phases of data cleaning and transformation.

During the data cleaning process, we had access to Excel files that contained columns such as "Tagname", "Timestamp", "MachineState", "Data Quality", "Percent Good", "Machine", "Shift Type", "Month", and "Year". Initially, these files were created separately for each machine, presenting a challenge for overall analysis and visualization. To simplify this process, we decided to merge the data from these individual files into a single file encompassing all machines. This step facilitated easier data manipulation and more effective visualization. During the data cleaning, we focused on ensuring consistency and accuracy in columns like "Tagname" and "Machine State", where it was necessary to normalize names and status values. In the "Data Quality" and "Percent Good" columns, we conducted a data quality check to ensure that the data entering the analysis were reliable and representative. This modification and consolidation of data provided us with a clean and integrated data foundation for subsequent project phases, including data transformation, modeling, and the eventual creation of the dashboard.

In the fourth step, "Data Transformation," we focused on advanced modifications by creating new columns representing various shift types like "Weekend Shift," "Morning Shift," etc. For this purpose, we employed formulas and commands that automatically assigned values to these newly created columns based on the content in the "Shift Type" column. For instance, if "Weekend Shift" was listed in the "Shift Type" column, the "Weekend Shift" column was automatically set to 1, while the columns for other shift types were set to 0. This method facilitated an easy back-check and ensured that the software correctly interpreted the data. It's important to note that "Weekend Shift" was considered a day shift (from 6:00 to 18:00), and no specific shifts were designated for days like Saturday and Sunday, with night shifts not occurring over the weekend. As an example, in a column named "Non-Working Time," a value of 0 would automatically appear based on specific

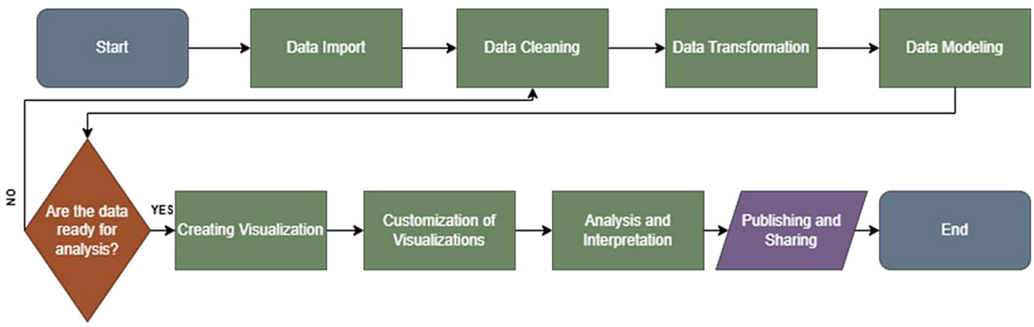

Figure 1. Flowchart of dashboard creation

commands if a "Weekend Shift" was indicated in the row and the "Timestamp" exceeded the mentioned working hours. This approach to data transformation and expansion was essential to ensure the accuracy of the analysis and the efficiency of the visualizations in the created dashboard. At this stage, we leveraged the advanced capabilities of the Power Query Editor for data transformations. Specifically, we utilized various tools within Power Query, such as "Promoted Headers" to set the first row as column headers and "Changed Type" to adjust data types for each column. These automatic steps provided a clean and structured data set. Further, we used the "Replaced Value" tool to rename machine states for clarity. For example, "Gtw02.Objects.DMG_CTX800.MachineState" was renamed to "CTX 800 BETA." This ensured that our data was coherent and ready for deeper analysis (Figure 2).

Additionally, we applied the "Append Queries" tool in Power Query to combine multiple CSV files into a single query named "DMG," allowing for comprehensive analysis across all machines. The transformation steps included renaming columns for better readability, such as changing "Tagname" to "Device" and "Timestamp" to "Recorded Time." We also converted numerical operational states to text descriptions, which provided clearer insights into machine performance. Further refinement involved creating custom columns using DAX formulas to facilitate detailed filtering and analysis. For instance, we created a "Month" column to display month names based on recorded timestamps, enhancing data readability (Figure 3). Another DAX formula was used to create a "Shift" column, categorizing data into morning, afternoon, night, and weekend shifts. This detailed categorization allowed us to analyze machine performance more precisely.

After data transformation, we paused for a crucial check, represented by the question: "Are the data ready for analysis?". This moment involved a critical reassessment of all preceding steps to verify if the data were in the correct state for analysis and visualization. It's important to note that our process map includes the possibility of a negative response to this question. Should the data not be considered adequately prepared – whether due to insufficient cleaning, incomplete transformations, or other deficiencies – it is imperative to return to the third step, "Data Cleaning". This cycle allows for iterative improvements in data quality before moving on to the final phases of visualization creation. Such an approach ensures that the dashboard creation process is not merely a linear progression but rather a flexible system that allows for necessary adjustments and enhancements based on the current state of the data. This method guarantees high quality and relevance of the outputs, which is crucial for effective data-driven decision-making processes.

After confirming that the data were ready for analysis, we proceeded with a series of steps focused on visualization: "Visualization Creation," "Customization of Visualizations," and "Analysis and Interpretation." These stages were crucial for transforming the analyzed data into visual representations that are intuitive and provide deep insights into performance and efficiency processes. In the "Visualization Creation" phase, we utilized

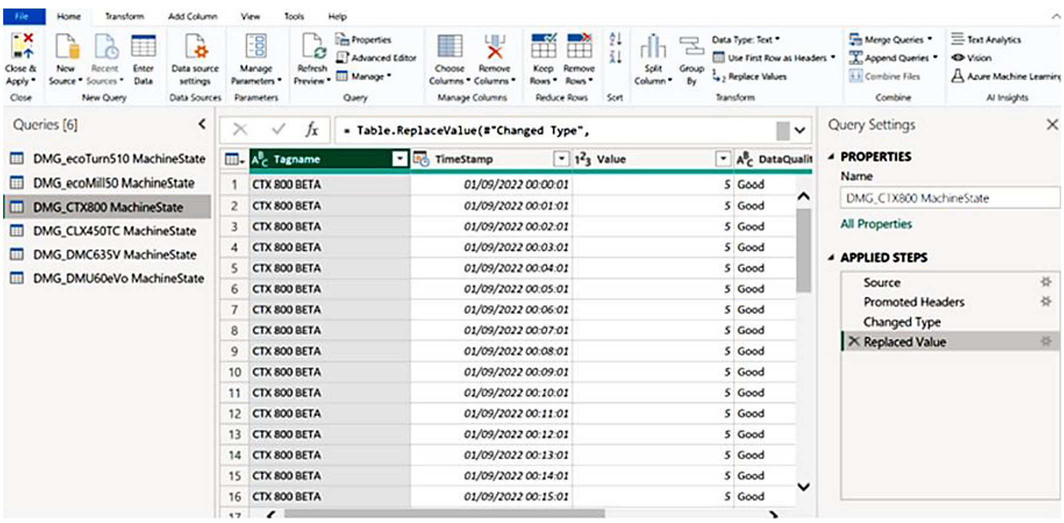

Figure 2. Power query editor: Promoted headers and changed type

```
Month =
VAR MonthNum = SWITCH(
    MONTH('DMG'[Recorded Time]),
    1, "January",
    2, "February",
    3, "March",
    4, "April",
    5, "May",
    6, "June",
    7, "July",
    8, "August",
    9, "September",
    10, "October",
    11, "November",
    12, "December",
    " Unknown"
)
RETURN MonthNum
```

Figure 3. Example of DAX formula for creating a custom "Month" column. Source: own research

various visualization tools and techniques available in Power BI Desktop to create dynamic and interactive graphs, pie charts, and other visual elements. Each visualization was intentionally designed to align with the analysis goals and the needs of the end-users, ensuring that the information was presented clearly and comprehensibly. The subsequent step, "Customization of Visualizations" involved tailoring the visualizations to meet the specific requirements of the company. This process included selecting color schemes that resonate with the corporate identity, adjusting detail levels for different user demographics, and incorporating interactive elements like filters and selectors, allowing users to personalize the visualizations according to their unique needs. Moreover, we explored the software's capabilities to create individual visualizations for each machine. However, after presenting our proposal and engaging in discussions with the company, we opted to develop a comprehensive dashboard. This dashboard features central pie charts that illustrate various "Machine States," complemented by additional filters – such as year, month, machine type, and shift type – arranged in a tile format. These tiles, when activated, enable users to visualize, delve into, and verify the specific conditions they wish to examine. This multifaceted approach not only facilitated effective data visualization but also laid the groundwork for deeper analysis and interpretation, significantly enhancing the data's utility for the company's decision-making processes. Consequently, the final dashboard emerged as a holistic tool that amalgamates technical accuracy, user-friendliness, and strategic value, effectively serving the company's needs.

After the successful visualization phase, we proceeded to the final step, "Publishing and Sharing". This step aimed to make the dashboard accessible to relevant stakeholders within the company, enabling the effective use of the information gathered for strategic decision-making. This final step concluded the entire dashboard creation process, providing companies with a powerful data analysis tool that supports informed decision-making and contributes to the organization's strategic agility. The result was a dashboard that became a key element in the process of data collection, analysis, and interpretation, offering essential information necessary for successful business management. This succinct summary encapsulates the essence and impact of the final step in the dashboard creation process.

The "End" step signifies the culmination of the dashboard creation process. At this point, the dashboard has been fully developed, tested, published, and made accessible to the intended users within the company. This stage represents the transition from development to practical application, where the dashboard starts to serve its purpose of aiding in data-driven decision-making and strategic planning. The conclusion of this process doesn't imply that the dashboard is static or final. Instead, it marks the beginning of its lifecycle within the organization, where it will be used, evaluated, and potentially updated based on user feedback and evolving business needs. The "End" step, therefore, is both a closure and a commencement, symbolizing the readiness of the dashboard to contribute to the company's ongoing success and adaptability.

RESULTS

The results section of the scholarly article meticulously examines the operational states of the company's DMG machines, inclusive of all five types of machinery. The pie chart provides a visual breakdown of machine states, with each segment representing different operational conditions encountered during their deployment (Figure 4). The largest segment of the chart, shaded in gray, represents the 'Power OFF' state, accounting for

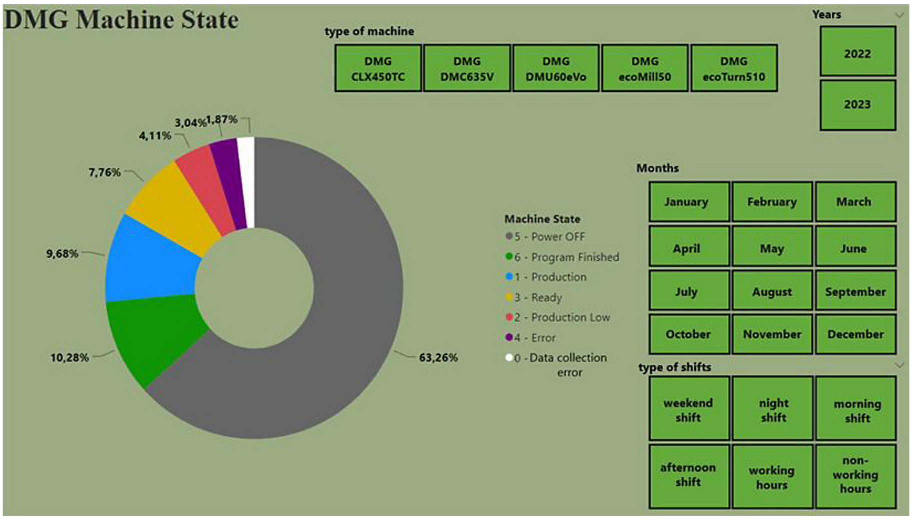

Figure 4. The resulting company dashboard

63.26% of the operational time of the machines. This significant proportion of downtime may indicate opportunities for enhancing the efficiency of equipment utilization.

The 'Program Finished' state is depicted in green, comprising 10.28% of the machine time. This could suggest periods when machines are on standby, awaiting further instructions, or being set up for new production cycles.

The 'Production' state, indicated in blue, occupies 9.68% of the operational time, reflecting active periods of manufacturing tasks.

The 'Ready' state, shown in yellow, encompasses 7.76% of the time, referring to moments when machines are set up and ready to commence production but are not yet performing any tasks.

'Production Low,' highlighted in red with a 4.11% share, points to times when machines are operating below full capacity.

Machine 'Errors', presented in purple, account for 3.04% of the operational time, signaling periods of technical disruptions or malfunctions.

Finally, the 'Data Collection Error', colored in white, constitutes a mere 1.87% of the time, which could indicate occasional issues with data gathering from manufacturing processes.

The dashboard offers a comprehensive set of filtering tools, allowing users to tailor the data display to specific requirements. The findings demonstrate the practical application of Power BI Desktop, echoing the tool's recognized role in converting complex data into actionable insights as highlighted in previous studies [3, 6]. The dashboard's filtering capabilities facilitate detailed analysis, in line with literature emphasizing the tool's adaptability in various contexts, from manufacturing to environmental health [9, 20].

On the right side of the screen are tiles for various categories that enable selection criteria:

1. Type of machine: Users can choose between different machine models (e.g., DMG CLX450TC, DMG DMC635V, etc.), specifying which machines the displayed data pertains to.
2. Years: Data can be selected for particular years (e.g., 2022, 2023), facilitating the analysis of long-term trends or the comparison of annual performance.
3. Months: Filtering by month provides data specific to each month, narrowing the analysis to seasonal patterns or evaluating performance in specific periods.
4. Type of work shift: Data can be segmented by the type of shift (e.g., weekend shifts, night shifts, morning shifts, etc.), which is useful for identifying variations in machine usage depending on the time.

It's important to note that the visualization displayed in the attached Figure 4. "The resulting company dashboard" represents the initial state of values without any filters from the right panel being activated. Thus, the pie chart illustrates the overall state of all the company's machines ("Machine State") without a specific focus on a particular machine type, year, month, or type of work shift. The results provide an aggregated overview of all operational states of the machines, allowing users to gain an immediate understanding of the overall efficiency and utilization of the machinery. By activating specific filters on the right side of the dashboard, users can then delve deeper into the data and explore specific aspects of machine performance based on selected criteria. The following figure presents a further level of detail, where specific filters have been applied to obtain a more focused view of the performance and usage of the particular DMG DMU60eVo machine.

Figure 5 shows the dashboard after activating filters that more specifically detail the operations of the DMG DMU60eVo machine during night shifts in November 2022. After applying these filters, it is evident that the machine did not record any power outages (‘Power OFF’) or data collection errors (‘Data Collection Error’) during the specified period. This provides clear evidence of the high-performance standards and reliability of this particular machine since it was able to operate continuously during the required night shifts. Furthermore, the ‘Production’ state (blue) accounts for the largest share at 36.36%, indicating that the machines were predominantly in active production. The ‘Ready’ state (yellow) and ‘Production Low’ state (red) each have an equal share of 18.18%, suggesting frequent readiness of the machines for production or their operation at lower capacity. The ‘Program Finished’ state (green) represents 22.73% of the time, indicating periods when the machines were prepared for further work but were not utilized. The least represented state is ‘Error’ (purple) at 10.28%, reflecting a relatively small amount of time during which the machines reported errors.

Figure 6 illustrates the dashboard after the activation of filters that specifically detail the

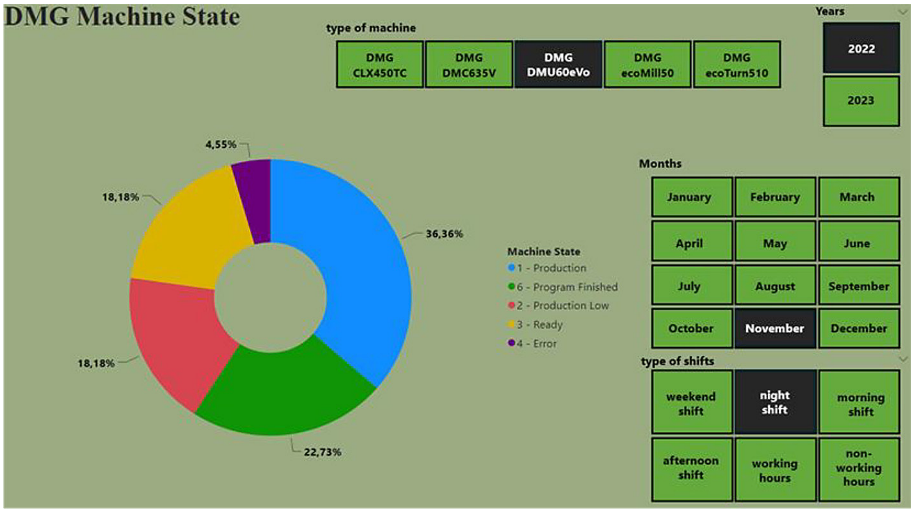

Figure 5. Dashboard for the DMG DMU60eVo machine 2023 after applying additional filters

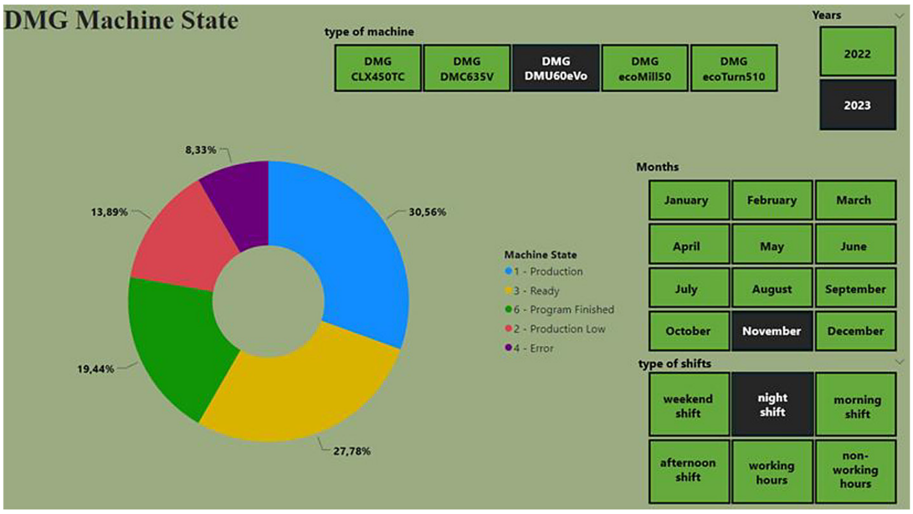

Figure 6. Dashboard for the DMG DMU60eVo machine 2023 after applying additional filters

operations of the DMG DMU60eVo machine during night shifts in November, albeit from a different year. The application of these filters shows, as in the previous period, that the machine recorded no power outages ('Power OFF') or data collection errors ('Data Collection Error'). This consistency affirms the machine's high-performance standards and reliability, as it operated without interruptions during the specified night shifts. In this case, the 'Production' state (blue) constitutes the majority at 30.56%, indicating that the machine was primarily engaged in active production. The 'Ready' state (yellow) accounts for 27.78%, suggesting that the machine was frequently in a state of readiness to commence production. The 'Program Finished' state (green) comprises 19.44% of the time, likely indicating periods when the machine was set up for subsequent tasks but was not active. The 'Production Low' state (red) makes up 13.89%, pointing to times when the machine was operating below its full capacity. The 'Error' state (purple) is the smallest at 8.33%, indicating that only a minor portion of time was impacted by technical issues or malfunctions.

It is important to highlight that in comparing this data with information from the previous year, we selected the same machine, month (November), and shift type (night shifts), which enables a direct comparative view of the machine's operational states across different years. The application of the same filters (same machine, month, and shift type) in different years allows for a direct comparison of the development of machine efficiency and reliability. This approach provides production management with valuable insights into whether the measures taken to optimize processes have yielded the expected improvements or if further steps are needed to increase productivity. Such a comparison also allows for the identification of trends in the operational states of the machines, which can support strategic decisions regarding maintenance and production planning. This comparison can provide valuable insights into the evolution of manufacturing processes, efficiency, and machine reliability over time.

These results reinforce the value of Power BI Desktop in providing nuanced, actionable insights that align with its established role in advanced data visualization and analysis, as supported by the literature [7–8, 12]. The integration of advanced filters and detailed visualizations in our study reflects the ongoing evolution of Power BI Desktop's capabilities in adapting to complex analytical needs.

DISCUSSION

The results of this study underscore the importance of Power BI Desktop as a powerful tool for data visualization and analysis, which is essential for the current business environment. The ability to visualize data effectively enables users to quickly comprehend complex datasets, identify trends, patterns, and anomalies, leading to more informed decision-making and improved strategies [31]. As noted by Aspin (2017) and Rad (2018), Power BI Desktop plays a critical role in business intelligence and data analysis by integrating diverse data sources to create comprehensive reports and dashboards [1-2]. This multifaceted capability was clearly demonstrated in our study within the manufacturing sector, where Power BI Desktop enabled more efficient monitoring and optimization of production processes. A detailed analysis of the percentage values of machine operational states revealed key areas for improvement. For example, a high percentage of 'Power OFF' time might indicate inefficiencies in planning and maintenance. Wright and Wernecke (2020) explain how Power BI Desktop visualizations can help identify and analyze these operational weaknesses, providing important insights for process improvement [5]. Furthermore, Hernández and Moreno (2021) highlight the benefits of mobile integration with Power BI Desktop, which allows real-time data access and improves decision-making speed and efficiency [6].

To avoid 'Production Low' or 'Error' states, it is crucial to implement a well-defined strategy based on insights gained from these visualizations. A robust strategy could include regular diagnostics and preventive maintenance, along with incorporating advanced analytics to predict and address potential issues before they impact production. This proactive approach can significantly enhance operational efficiency and reduce the frequency of downtime and errors.

When considering the low levels of 'Error' states, it is necessary to consider the possibility of inadequate diagnostics or imperfections in data records. Innovations in AI and machine learning, as suggested by Ehrenmueller-Jensen, could enhance Power BI Desktop's capabilities in predicting and quickly identifying potential issues before they impact production [8].

In terms of adaptability, as demonstrated by Bublyk et al. in environmental analysis, Power BI Desktop can effectively process and visualize complex data sets, which is invaluable for addressing specific challenges such as environmental studies and resource management [16]. To illustrate how Power BI Desktop compares with other leading data visualization tools, we have included a comparison table below. This table provides a detailed analysis of key factors such as functionality, visualization focus, industrial applications, integration with business systems, collaboration, and data visualization capabilities across Power BI Desktop, Tableau, and Qlik Sense. This analysis offers an overview of these tools based on criteria relevant to the manufacturing sector.

The comparison presented in the Table 1 highlights the key features of Power BI Desktop relative to other leading data visualization tools, namely Tableau and Qlik Sense. Each tool is designed to address different needs and contexts effectively. Power BI Desktop is particularly suited for manufacturing companies that need to optimize processes and analyze large volumes of data. It integrates well with Microsoft products, which is advantageous for organizations already using these systems. The tool's focus on structured data and performance monitoring aligns with the requirements of manufacturing environments where operational dashboards and KPI tracking are essential. Its integration capabilities and user-friendly interface make it a practical option for companies seeking a data analysis solution that fits within their existing Microsoft ecosystem [32–33].

Tableau is known for its strong capabilities in creating interactive and visually compelling visualizations. It is effective for industries that require detailed and aesthetically appealing data representations, such as marketing and design. While Tableau offers extensive customization options and robust visualization features, its premium pricing and potentially complex interface may present challenges for some users. It is well-suited for scenarios where advanced data processing and rich visual presentations are required [34–35].

Qlik Sense excels in handling large datasets and providing real-time interactive analysis. It is suitable for industries like finance, logistics, and supply chains that need detailed process tracking. Its flexibility in customization and broad data source integration makes it a strong competitor. However, like Tableau, Qlik Sense has a premium pricing model that could be a consideration for budget-conscious organizations [36–37].

The choice of Power BI Desktop for this study was exclusively influenced by the specific needs of our partner company. The company required a tool that would meet their need for cost-effectiveness, allow seamless integration with existing Microsoft systems, and be user-friendly. This tool effectively meets all these requirements and provides a solution that integrates smoothly with the existing infrastructure while supporting the company's manufacturing data analysis needs. [38–39].

Our practical experience confirmed these benefits. Users consistently reported that the

Table 1. Comparison of data visualization tools

Feature	Power BI desktop	Tableau	Qlik sense
Best suited for	Manufacturing companies needing to optimize processes and analyze large volumes of data; firms with existing Microsoft infrastructure	Industries focused on marketing, design, and creativity that require dynamic and aesthetically appealing visualizations	Companies in finance, logistics, and supply chains needing real-time interaction
Focus on visualization	Strong operational dashboards, key performance indicators (KPIs), and manufacturing efficiency analysis	Creative, interactive visualizations, ideal for marketing and design	Complex interactive visualizations, excellent for detailed tracking of real-time processes
Integration with business systems	Seamless integration with Microsoft platforms (Excel, Dynamics, Azure), ideal for companies using these systems in manufacturing	Flexible integration but may require more complex configuration	Strong integration with external systems, excellent for advanced data preparation and real-time analytics
Collaboration	Seamless collaboration within the Microsoft ecosystem, ideal for manufacturing teams and management	Quality collaboration tools, higher costs for sharing	Efficient information sharing and collaboration, suitable for medium and large teams
Data visualization capabilities	Focused on structured manufacturing data and process dashboards, ideal for tracking production KPIs and identifying bottlenecks	Excellent for exploratory visualizations, less focused on the manufacturing environment	Highly interactive, suitable for real-time data tracking and analysis, less flexible for structured processes

visualizations provided by Power BI Desktop enabled more accurate and faster decision-making, particularly regarding operational efficiency and resource allocation. For instance, the tool helped to pinpoint machine downtime patterns, leading to concrete actions to optimize manufacturing processes. The findings from this comparison suggest that while other tools like Tableau and Qlik Sense offer compelling features, the combination of cost-effectiveness, ease of use, and robust functionality of Power BI Desktop makes it the most suitable choice for this case study. This evaluation supports our recommendation for Power BI Desktop, particularly for organizations looking to leverage a powerful and adaptable data visualization tool while maintaining cost efficiency.

Given this context, it suggests that Power BI Desktop could be further extended into other sectors where complex data analyses can lead to significant improvements and innovations. While our current research provides a foundational comparison, future studies should include practical applications of Power BI Desktop in real-world settings. Specifically, comparing its performance with other tools such as Tableau and Qlik Sense through case studies involving different companies will offer deeper insights into its strengths and areas for improvement. Such comparisons could illustrate the tool's versatility and potential in diverse applications.

In future research, it would be valuable to not only continue comparing Power BI Desktop with other data visualization tools but also to explore practical implementations of these tools in various organizational contexts. This approach will help in understanding how different features of these tools perform in real-world scenarios and meet the specific needs of different industries and use cases. Such practical explorations will also offer insights into the real-world challenges and opportunities that arise during the implementation process, as demonstrated in our collaboration with the client.

Collaboration with our client during the development process introduced both challenges and opportunities. One of the main challenges was aligning the diverse expectations of stakeholders. The client had high demands for the precision and speed of visualizations, while technical limitations of data sources and systems presented obstacles. Resolving these conflicts requires regular meetings, continuous testing, and iterative development, where we progressively fine-tuned the functionality and design according to user needs. This process highlighted the importance of ongoing dialogue between the development team and end users.

On the other hand, certain aspects of the development worked exceptionally well. The flexibility of Power BI Desktop and its ability to work with multiple data sources allowed us to quickly respond to the client's requests and customize the dashboard to the company's specific needs. Clients particularly appreciated the intuitive interface and clear visualizations, which enabled them to analyze large volumes of data more easily.

After implementing the dashboard, feedback from users confirmed its value. Users reported that the visualizations helped them better understand complex data and facilitated the decision-making process. The dashboard was widely adopted by both management and operational teams, who use it regularly to monitor manufacturing processes and identify areas for improvement. With these tools, they were able to pinpoint key issues, such as inefficient machine downtimes, and take concrete actions to improve efficiency.

Based on our findings and literature review, we recommend further studies comparing Power BI Desktop with other data visualization tools to clarify its most effective aspects and identify areas for enhancement. Given the dynamics and rapidly changing market demands, it will be crucial for Power BI Desktop to continue integrating new technological trends, such as cloud technologies, IoT, and advanced data analytics. Tyulepberdinova and Suleimen discussed the possibilities of expanding Power BI Desktop into cloud applications, which could significantly enhance its capabilities and accessibility [20].

While we have conducted initial comparisons and planned practical visualizations in our current research, we recognize the need for broader and more detailed exploration. Future research will expand our literature review to include additional studies covering various aspects of dashboard design and data visualization across different sectors. This expanded review will provide a more comprehensive understanding of the development and applications of data visualization tools and their effectiveness in real-world scenarios. These findings and recommendations indicate that Power BI Desktop has strong potential for further improvement and adaptation to the needs of various users and industries. Future research should focus on these aspects to ensure that Power BI Desktop remains at the forefront of business intelligence and data analytics.

CONCLUSIONS

This article has extensively examined the implementation and impacts of Power BI Desktop in business intelligence and data visualization, outlining its role in the development of analytical tools. From the literature review that illustrated the historical evolution and key milestones of Power BI Desktop to a detailed analysis of its applications across various industrial sectors, this paper has provided a deep dive into its capabilities and usage.

The literature review highlighted how, since its launch in 2017, Power BI Desktop has helped organizations transform complex datasets into interactive reports. The review also showed how Power BI Desktop has become a key tool in business intelligence and other fields such as education and environmental management, illustrating its versatility and adaptability.

The methodology of developing a dashboard, implemented in collaboration with a manufacturing company, was critical in demonstrating the practical application of Power BI Desktop. The development of the dashboard was thoroughly documented, including critical phases such as data collection, transformation, and subsequent visualization. This process was not just about technical execution but also about adapting the tool to the specific needs of the firm, highlighting the flexibility of Power BI Desktop.

Our detailed procedure for creating the dashboard included essential steps such as data import, cleansing, transformation, modeling, and customization of visualizations. Each of these steps was meticulously designed to ensure the accuracy and relevance of the data, culminating in a user-friendly and strategic tool for the company's decision-making processes. The use of Power Query Editor for data transformations and DAX formulas for creating custom columns significantly enhanced the data's readability and usability.

The results of our study showed how data visualization through Power BI Desktop could uncover key areas for improvement and increase the efficiency of manufacturing processes. For instance, analytical insights provided by Power BI Desktop enabled the identification and addressing of areas with a high percentage of machine downtime, leading to significant opportunities for productivity enhancement.

However, our study also encountered limitations, such as a limited scope of data or constraints in certain sectors, which may affect the generalizability of our findings. Future research should address examining the tool's performance in various industries or assessing user experiences across different contexts. These studies could offer insights into more effective use of Power BI Desktop and potential new features.

Future integration with cloud technologies and IoT could extend the capabilities of Power BI Desktop. These advancements could enable greater decentralization of data processing and real-time analysis.

In conclusion, Power BI Desktop has proven to be an indispensable tool in the modern environment of business intelligence and data analytics. Its ongoing development and adaptability to changing market demands underscore the need for continued innovation and research to keep it at the cutting edge of technological advancement. Monitoring and leveraging new opportunities for Power BI Desktop will ensure its relevance and effectiveness in business and technology.

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