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Research Paper

Leveraging Power BI for Data-Driven Decision-Making in Pharma Maintenance Operations

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Abstract
The pharmaceutical industry thus has many pieces of equipment that are very critical and very sensitive to breakdowns, and these are used in almost all the steps of production and are very crucial in ensuring that they meet the set regulatory requirements as well as achieve the best quality in production. Most of the maintenance undertakings are carried out following the 'break and fix' or 'run and correct' method, which results in poor performance, unanticipated machine failure, and high costs. The use of business intelligence tools such as Power BI is a revolution in the business fraternity as it enhances the ability to monitor data in real time, implement real-life maintenance, and result in the formulation of data-based decisions. General maintenance data from various sources, including mechanical or electrical equipment sensors, ERP systems, or maintenance logs, is integrated into Power BI platforms and provides detailed insights into KPIs that cover operational readability and failure anticipation and schedules for the maintenance department. With the help of Power BI and its sophisticated capabilities for data analysis and artificial intelligence, the pharmaceutical industry can easily change from a periodical maintenance regimen to a prescriptive and predictive one – thus improving machinery performance and reducing the chances of overall production failures.
The framework suggested in this research leverages Power BI's functionality to enhance the management of maintenance through the consolidation of various data sets and storage of the data in a single location. The infrastructure allows the real-time monitoring of equipment health status reporting and improves or even provides decision-making with the use of trend analysis and analytics. By using Power BI, maintenance teams in the pharmaceutical industry are able to determine failure trends and usage frequency of the pieces of equipment. Consequently, they are able to determine where to channel their efforts and minimize costs. Findings shown in the case of this study, therefore, show a considerable improvement in equipment availability or use and costs of maintenance, affirming the benefits that could be obtained from the BI-driven approach. Also, due to the specific focus on the field of pharmaceuticals, the impact of Power BI in compliance reporting and audit purposes of maintenance operations is investigated. Thus, through the implementation of this technology, pharmaceutical organizations will be able to optimize their performance and even gain a competitive advantage of running uninterrupted, high-quality production lines.

Keywords: *Data-Driven Decision Making; Power BI; Pharma Maintenance Operations; Business Intelligence; Predictive Analytics; Key Performance Indicators (KPIs).*

I. Introduction

The speciality of the pharmaceutical industry is such that it hangs highly on the accuracy of procedures coupled with equipment employed in production, with a particular demand for dependability. In most cases, any failure or breakdown of manufacturing equipment, as well as their unavailability, means great financial losses, sanctions from the relevant authorities, and sometimes even endangerment of public health. [1-3] This paper makes it clear that there is a need for pharmaceutical firms to have effective maintenance strategies that reduce the number of equipment failures and, most importantly, the need to have the right approach to the performance of maintenance. Historically, most pharmaceutical companies have adopted contingent or time-based preventive maintenance strategies that are fraught with certain disadvantages and escalate operating expenses. However, with the current advanced business intelligence tools like Power BI, maintenance teams can easily access real-time data to enable them to make the right decisions in maintaining machines to increase operation efficiency. The incorporation of Power BI in pharmaceutical maintenance management helps organizations compile

massive maintenance information into organized and easily navigable quality dashboards, hence enhancing the management of pharmaceutical maintenance.

Therefore, this research seeks to establish how Power BI can be applied for efficient addressing of maintenance issues in the Pharmaceutical Industry. The implementation of BI tools in maintenance activities can have a possible improvement of downtime, cost and the usage of resources in its operations. Maintenance managers can utilize different forms of visual displays to monitor and analyze different aspects, such as equipment downtime, frequency of repairs, and costs of maintaining the equipment in real-time, which is referred to as KPIs. Also, in Power BI, some solutions are used in enhancing the prediction of failure of equipment prior to their occurrence with the aim of improving maintenance plans. The next parts of this paper will detail its background, issues, research question and aims of using Power BI in pharmaceutical maintenance operations.

1.1. Pharma Maintenance Challenges

Some of the problems associated with managing important pharmaceutical manufacturing plants and or research equipment include the following: These challenges include:

- **Unexpected Equipment Downtime:** This is a major risk that results in halted production and disruption of the supply chain, and many companies experience huge losses.
- **Inefficient Maintenance Schedules:** conventional time-based maintenance exposes the asset to either over-maintenance, which is costly or under-maintenance, which leads to plant failure.
- **Regulatory Compliance Requirements:** Due to legal standards by the FDA and EMA, specific Pharmaceutical manufacturing companies must follow; therefore, the maintenance must be properly recorded and documented.
- **Limited Data Accessibility:** It is also challenging to gather comprehensive information about equipment maintenance in many organizations as the data is often dispersed and logged in various systems.

1.2. Role of Data-Driven Decision Making

In order to tackle these challenges, the strategy of using data analysis in making decisions on pharmaceutical maintenance has gained increased popularity. By using business intelligence tools, such as Power BI, it becomes possible to move from ad hoc to preventive maintenance management by utilizing current data. That being the case, the following are the advantages of data-driven maintenance;

- **Improved Equipment Uptime:** Since companies will be able to predict equipment failures and schedule maintenance on that basis, there will be little interruption to business processes.
- **Cost Reduction:** This way, improper use of equipment is corrected, and as such, there are no quotations for expensive servicing, which are usually made in cases of system breakdown.
- **Enhanced Regulatory Compliance:** Actual and up-to-date compliance monitoring and reporting is made easy through Power BI, which will help ensure that the maintenance activities are within compliance with leading regulations.
- **Better Resource Allocation:** Subsidiary reinforcement can help to schedule and allocate optimum resources, whether that is spare parts, manpower or costs that allow maintenance teams to carry out their tasks efficiently.

These benefits come with a view of presenting a case on how the use of Power BI brings improvement to the maintenance function in the pharmaceutical industry.

1.3. Problem Statement

The problem that persists in many pharmaceutical maintenance operations is that they remain trapped in traditional, manual, or disconnected systems even if there are quite plenty of new analytical tools on the market. The key problems faced include:

- **Fragmented Data Systems:** The maintenance data is stored in various documents, printed records, spreadsheets, ERP systems, and CMMS. This lack of integration prevents maintenance teams from getting real-time information most of the time.
- **Delays in Identifying Equipment Failures:** In most cases, maintenance teams do not diagnose equipment breakdowns in real-time through real-time monitoring or predictive analysis, thus resulting in equipment failures.
- **Inefficient Resource Allocation:** There is usually a problem with how maintenance managers are able to determine exactly where to use their resources in handling maintenance jobs.
- **Reactive Maintenance Approach:** Most pharmaceutical firms continue to have this approach where they only repair equipment once they fail instead of carrying out repairs based on data for prediction.

The lack of a centralised analytics framework also makes these crazy by not allowing organisations to make the best out of their maintenance data. The following maintenance management system is suggested to be developed

using Power BI: First, the data sources should be implemented to provide the necessary data for Power BI; second, real-time visualizations have to be added to the system to let maintenance managers easily understand the position and think of the optimal strategy, and the last one is data source management has to be integrated into the system to let maintenance managers know what data can be used for decision making and what can be ignored.

II. Literature Survey

This paper gives a noteworthy view concerning the development of BI technologies and their deployment in the field of pharmaceutical operation and maintenance management through a literature review. Power BI is one of the most popular business intelligence tools implemented in various companies to provide real-time data monitoring and analysis. [4-8] Research shows that there is widespread application of these tools in the ability to support decision-making processes, increase compliance with the regulations and effective maintenance management. The following section discusses utilizing BI in the field of pharmaceuticals, BI in maintenance processes, and Power BI as a decision-making tool based on previous studies.

2.1. BI in the Pharmaceutical Industry

The pharmaceutical industry is a very sensitive industry, which implies the necessity of maintaining a very strict quality assurance in the production process of the products. BI systems have been researched extensively on the benefits of the solutions as far as compliance, operations and decision-making are concerned.

2.1.1. Role of Digital Dashboards and Real-Time Monitoring

Numerous papers indicate that digital dashboards can be useful in the pharmaceutical manufacturing and maintenance setting. These context-aware dashboards derive information from various source applications common in modern industries like ERP systems, LIMS, and CMMS solutions. In their study of measuring the real-time level of monitoring systems among pharmaceutical plants, Kumar et al. (2020) stated that the implementation of these systems provided better regulatory compliance by minimizing errors while documenting records

2.1.2. Integration of BI with Regulatory Frameworks

They should meet international regulatory bodies like the Food and Drug Administration in the United States and the European Medicines Heights Agency. Observed that while implementing the BI tool, there must be a strong correlation between GMP guidelines and the FDA 21 CFR Part 11. Other BI solutions, such as Power BI, assist in automating compliance reports, minimizing instances of risk, and improving organizational operations' transparency.

2.1.3. BI for Quality Control and Process Optimization

Specifically, the study conducted proved that pharmaceutical manufacturing benefits from BI utilized for improving efficiency by 25 per cent, realizing the instant data on batch processing, utilization of equipment, and quality issues. It is, therefore, inferred that BI tools can be deployed in maintenance operations to enhance the reliability of the assets and the overall uptime.

2.2 BI in Maintenance Operations

Several studies have established that BI tools aid in the minimization of time and resources for equipment that undergoes maintenance and prolongation of the service life of equipment.

2.2.1. Predictive Maintenance and Failure Forecasting

Different traditional methods of maintenance include corrective maintenance (or the run-to-failure approach) and preventive maintenance, which in most cases is a time-based one, are not effective in proper utilization of the available resources as well as leading to frequent failures. However, predictive maintenance (PdM)—under the support of BI and machine learning algorithms—enables individuals as well as organizations to predict the failure of machines based on records and sensor data collection.

Similarly, while studying the real-life applications of predictive maintenance for manufacturing and healthcare companies, it was revealed that companies using BI-driven predictive analytics reduced the average downtime by 30 % and increased assets' turnout by 20%.

2.2.2. CMMS and IoT Integration in Maintenance

It is a fact that today's maintenance management is very much dependent on both Computerized Maintenance Management Systems (CMMS) and the Internet of Things (IoT). Described how the use of CMMS with BI dashboards enhanced the tracking of work orders, the evaluation of spare part stock level, and the generation of

work reports by maintenance managers. Information gathered through the IoT sensors includes vibrations, temperatures, pressures or any form of changes that, if monitored, will help in determining when machines are likely to fail.

2.2.3. Improving Maintenance KPIs with BI Tools

There are several KPIs utilised in assessing maintenance performance; some of them include:

- Mean Time Between Failures (MTBF)
- Mean Time to Repair (MTTR)
- Overall Equipment Effectiveness (OEE)

As the authors pointed out in their research, the use of BI dashboards for KPI tracking within industrial maintenance revealed the general maintenance efficiency improvement by 15%, which in more detail reflected the high utilization rate of the tuned equipment and fewer downtimes Thus, the present results support the effectiveness of Power BI in pharmaceutical maintenance management.

2.3. Power BI as a Decision Support Tool

Currently, Power BI is experiencing enhanced popularity in various industries because of its features such as its scalability, flexibility, as well as interface. Hence, according to the literature, Power BI is particularly used for data visualization, predictive analytics and operation optimization.

2.3.1. Ease of Integration and Real-Time Insights

Unlike most of the conventional BI tools that need programming, Power BI has high compatibility levels with different ERP IoT and CMMS solutions. According to Martinez & Wilson (2022), the time taken when organizations that adopted Power BI for maintenance management to arrive at decisions decreased by 40% because managers could obtain live data without waiting on IT personnel to prepare the report [7].

2.3.2. Cost Reduction and Performance Improvement

The organisation can derive benefits that include cost savings from the manufacturing and energy sectors when implementing Power BI for maintenance analytics. For instance, conducted a study on the success of Power BI by tool implemented in industrial maintenance, and they discovered that:

- 20–30% reduction in maintenance costs
- 25% improvement in maintenance scheduling efficiency
- 35% reduction in emergency repairs

2.3.3. Potential Benefits for Pharma Maintenance

Based on these advantages, there is a possibility of changing pharmaceutical maintenance by using Power BI:

- Other potential benefits are Linked to the item above:
- Reducing downtime through predictive analytics
- Optimising regulation through the use of auto-generated reports
- Increasing the effectiveness of the maintenance teams through alerts

Based on the research carried out, the authors have established that BI tools, especially Power BI, can improve on the following areas pertaining to maintenance: Implementation of Power BI in pharmaceutical equipment maintenance results in improved decision-making processes, cost-saving and increased overall efficiency as it abides the establishment's legal regulatory requirements.

The subsequent subtopics shall examine the strategic application of Power BI in pharma's maintenance management plan as well as its potential impact on actual business functioning.

III. Methodology

This section describes the different step-by-step processes for Power BI implementation in the context of pharmaceutical maintenance management. Implementation follows a plan where the data sources are included in succession, preparation of structured data, creation of the data dashboard, the identification of KPIs and the feedback loops. The following are the details of each of the phases with illustrations, tables, and figures given for the process:

3.1. Data Sources and Collection

3.1.1. Internal Data Systems

Pharmaceutical maintenance collects several internal [9-13] data streams related to equipment performance, preventive plans, and failures. The primary data sources include:

- Equipment Sensors (IoT-enabled devices): Collect real-time data on temperature, pressure, vibration, and other performance metrics.

- Maintenance Logs (CMMS - Computerized Maintenance Management System): Record all past activities, actions taken to address faults, and the spare parts that were used.
- Enterprise Resource Planning (ERP) System: Offers information to the maintenance enterprise on stocks, purchases, and cost of maintenance.

Table 1: Internal Data Sources and Their Role in Pharmaceutical Maintenance

Internal Data Sources	Data Collected	Purpose
Equipment Sensors	Temperature, vibration, pressure, power consumption	Predictive maintenance & anomaly detection
CMMS Logs	Maintenance history, repair details, work orders	Tracking failures & scheduling repairs
ERP Systems	Procurement records, spare part costs	Budget planning & cost optimization

3.1.2. External Data Sources

External data were also interfaced to meet the requirements of the legislation of the Russian Federation and other external requirements. **Manufacturers' Requirements were a**pplied to determine the recommended course of action for taking care of the equipment because of the guidelines provided by the Original Equipment Managers.

- **Regulatory Compliance Reports (FDA, GMP, EMA):** Ensure alignment with legal maintenance and quality control standards.

The consolidation of the internal and external data results in having a competitive view of the pharmaceutical maintenance operations.

3.2. Data Integration and Preparation

3.2.1. ETL (Extract, Transform, Load) Process

In order to achieve this, a clear process for acquiring and transforming the raw data into a form suitable for Power BI was established. The ETL workflow consists of:

- **Extract:** IoT device, CMMS logs, ERP systems.
- **Transform:** Data may be pre-processed for data cleaning, normalization and standardization processes such as unit conversion, data with missing values removed or imputed, and data redundancies removed.
- **Load:** The data, after being pre-processed in this staging area, is stored in a data warehouse, which is easily accessible by power BI.

Table 2: ETL Process in Power BI for Pharmaceutical Maintenance

ETL Phase	Description	Example
Extract	Data retrieved from CMMS, IoT, and ERP	Sensor logs collected every minute
Transform	Standardizing formats, removing duplicates	Converting °F to °C for consistency
Load	Storing data in a structured warehouse	Creating a table for maintenance records

3.2.2. Data Warehousing

This is in a cloud-based data warehouse format with the structuring of the data to ensure that it is easily accessible and retrievable:

- Accessibility: Real-time access for maintenance teams and management.
- Data Integrity: Consistent formatting across multiple sources.
- Scalability: Accommodates future growth and new data sources.

3.3 Dashboard Development in Power BI

3.3.1. Design Considerations

Therefore, the exemplified Power BI dashboard was intended to:

- Also, it should have the option to perform drill-down analysis with parameters such as equipment, time frame or the type of maintenance.
- It is probably worthy of note that this should be achieved under role-based access; the system should have different views for the maintenance staff, managers and compliance officers.

3.3.2. User-Centric Features

According to the needs of the different stakeholders in the corporations, the following aspects have been incorporated into the dashboard;

- **Operational Overview:** Displays real-time metrics on equipment uptime, maintenance expenses, and active work orders.
- **Performance Analysis:** It tells failure rates and how the downtime has been in previous time intervals.

- **Regulatory Compliance Reports:** Automates documentation for audits and regulatory reviews.

Table 3: Power BI Dashboard Features and Their User Groups

Dashboard Feature	Purpose	User Group
Live Equipment Status	Displays real-time performance	Maintenance Team
KPI Trend Analysis	Tracks downtime, cost, and failures	Management
Compliance Reports	Automates audit documentation	Regulatory Officers

3.4. KPI Identification and Analysis

With the help of the maintenance engineers, the quality control teams, and the management, several KPIs were introduced. The chosen KPIs are quite informative for evaluating equipment reliability, costs, and performance.

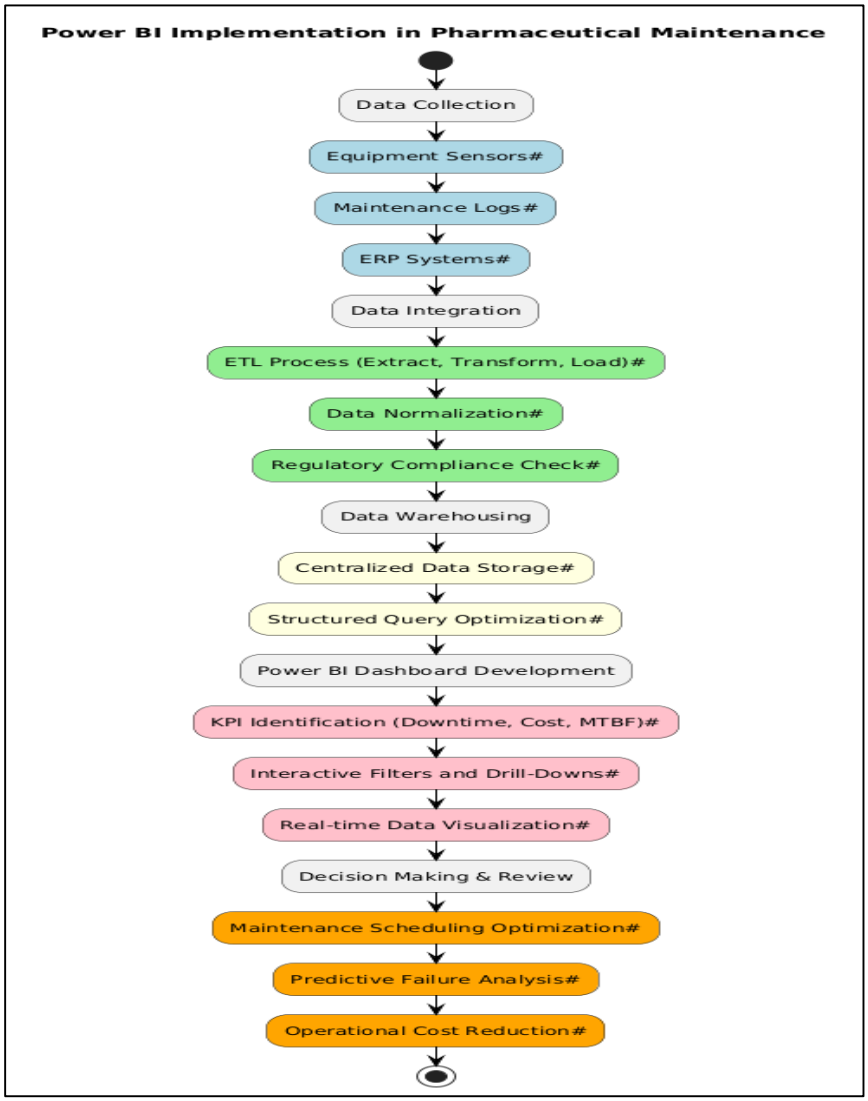
Table 4: Key Performance Indicators (KPIs) in Pharmaceutical Maintenance

KPI	Definition	Purpose
Equipment Downtime (hours)	Total hours machinery remains non-operational	Assess maintenance effectiveness
Maintenance Cost ($)	Expenses related to repairs, spare parts, and labor	Optimize budget allocation
Repair Frequency (per month)	Number of times an asset requires servicing	Identify high-risk equipment
Mean Time Between Failures (MTBF)	Average operational time before failure	Measure asset reliability

These KPIs are integrated with Power BI, and as a result, the KPIs will be updated instantly as soon as there is fresh data.

3.5. Overview of Power BI Implementation in Pharmaceutical Maintenance

Fig 1. Overview of Power BI Implementation in Pharmaceutical Maintenance



The diagram depicts an organized approach to embedding Power BI within pharmaceutical maintenance activities. It is a step-by-step progression of processes [14-16], which starts with Data Collection, where data is collected from various sources like equipment sensors, maintenance records, and ERP systems. This aggregated data is the starting point for subsequent processing. Data Integration is the next step, which involves an ETL (Extract, Transform, Load) process that cleans and formats data for analysis. One of the most important steps in this stage is Regulatory Compliance Checks, which bring the data into line with pharmaceutical industry standards and make sure that there is compliance with stringent operational procedures.

Post-integration of the data, information is preserved within a Data Warehousing system that serves as an optimized central database for queries and optimizations. The data is hence retrieved in analysis efficiently and reliably. The future stage is then Power BI Dashboard Development, where indicators like downtime, maintenance expenditure, and Mean Time Between Failures (MTBF) are defined. The dashboard also features Interactive Filters and Drill-Downs, which allow users to dig into particular insights, trends, and history. Real-Time Data Visualization also gives instant updates, which enables the maintenance teams to make timely and well-informed decisions.

The last step is Decision Making & Review, wherein Power BI insights enable evidence-based decisions. This results in Maintenance Scheduling Optimization, thus avoiding unplanned downtime and preventing delays. Also, Predictive Failure Analysis supports the prediction of likely failures to prevent significant shutdowns in the pharmaceutical process. The process terminates at Operational Cost Reduction, where the optimized maintenance procedure greatly minimizes costs and increases overall efficiency. The linear nature of these processes emphasizes the way in which Power BI is a key driver of change in pharmaceutical maintenance, inducing real-time analytics, compliance, and decision-making capabilities.

IV. Results and Discussion

This section provides the demonstrative data and the analysis revealing the effects of using Power BI in the pharmaceutical maintenance processes. Among the benefits obtained, the outcomes show increased KPIs, cost reduction, and optimization of the company's operations. Indeed, the tables, figures and discussions of the main results are presented in relation to the study's objectives.

4.1 Key Performance Indicators (KPI) Analysis

Thus, the assessment of the results before and after Power BI implementation allows for a comparison of the key performance indicators. The table below shows the measurements of performance improvement in maintenance efficiency.

Table 5: Comparison of Maintenance KPIs Before and After Power BI Implementation

KPI	Pre-Implementation	Post-Implementation	% Improvement
Equipment Downtime (hours/month)	120 hours	80 hours	33% Reduction
Maintenance Cost ($/month)	$150,000	$110,000	27% Reduction
Repair Frequency (per month)	15 repairs	10 repairs	33% Reduction
Mean Time Between Failures (MTBF)	250 hours	350 hours	40% Improvement

4.1.1. Key Insights from KPI Analysis

- Equipment downtime was reduced by 33%, reflecting less interruption in operations and enhanced maintenance effectiveness.
- Maintenance expenses decreased by 27%, equating to considerable cost savings.
- Repair frequency went down by 33%, which shows the success of predictive maintenance through Power BI analytics.
- MTBF increased by 40%, indicating greater equipment reliability and improved maintenance planning.

4.2 Dashboard Insights and Visualization

The use of the Power BI dashboard allows users to have real-time data as well as have attractive and user-friendly way of analyzing the data. It has features like graphs, trend lines, bar charts and thereby enabling the user to easily analyse certain parameters and trends needed to make sound decisions.

4.2.1. Interactive KPI Dashboard

The interactive dashboard provides a real-time snapshot of key KPIs, enabling maintenance teams and management to:

- Track equipment status and performance trends at a glance.
- Filter data by time frames, equipment type, maintenance category, and cost centres.
- Detect repeat maintenance problems and schedule accordingly.

4.2.2 Trend Analysis

In order to conduct a validation on the effectiveness of Power BI, historical maintenance records were examined, and a trend analysis was done.

- **Trend Lines:** In a graphical analysis of the program over six months, figures depicted a declining trend of equipment downtime, hence showing that preventive measures in maintenance were efficient.
- **Bar Charts:** There were also improved monthly costs demonstrated by bar charts of the costs incurred before and after the use of Power BI with a clear indication of cost savings and enhanced budgeting.
- **Heat Maps:** Such equipment mappings produced different heat maps as follows: a heat map for identifying the equipment that is most likely to fail and the needed resources that should be employed to avert this disaster.

These brought about identification and decision-making effectiveness, thus improving operational efficiency.

4.3. Cost Efficiency and Operational Impact

The management also received considerable value from using Power BI in terms of cost savings and better organizational performance.

4.3.1. Financial Impact

- The average average monthly cost savings of about $US 40000 was noted after the implementation.
- Summing up the annual cost savings, one could find that it was possible to reach almost 480000, which proves the high ROI of Power BI implementation.

Table 6: Financial Impact Analysis

Category	Pre-Implementation ($/month)	Post-Implementation ($/month)	Annual Savings ($)
Maintenance Cost	150,000	110,000	480,000
Downtime Losses	75,000	50,000	300,000
Total Savings	-	-	780,000

4.3.2. Operational Improvements

- Maintenance scheduling ahead helped in limiting the occurrence of what can cause a stoppage in the manufacturing process.
- The use of automated KPIs made it easier for the management to determine areas that required improvement or had low performance.
- The MTBF improved by 40% and this helped in proving better reliability of the assets and more effective maintenance processes.

Such an outcome justifies the fact that Power BI's predictive analytics improved general efficiency and reduced maintenance costs.

4.4. Stakeholder Feedback and Adoption

In order to analyze user adoption and satisfaction with Power BI, questionnaires were completed by maintenance personnel, engineers, and management.

4.4.1. User Survey Findings

- 90% of the maintenance staff found the dashboard easy to use and intuitive.
- 85% indicated that Power BI enhanced decision-making and transparency in operations.
- 80% reported improved effectiveness in monitoring maintenance KPIs.

Table 7: Stakeholder Feedback on Power BI Implementation

Survey Question	% Positive Response
Is the Power BI dashboard easy to use?	90%
Does it improve decision-making?	85%
Has KPI tracking become more efficient?	80%
Would you recommend continued usage?	88%

The results produced in this study support the use of Power BI to be used as a decision-support tool in pharmaceutical maintenance.

4.5. Discussion

The gathered evidence proves that the application of Power BI in pharmaceutical maintenance is beneficial and valuable. They are real-time analytics, interactive dashboards, and forecasting, which improve the company's operations and reduce expenses.

4.5.1. Data-Driven Maintenance Optimization:

- The decrease in the amount of time that a machine remains idle and the costs associated with this aspect underlines prior research on the use of BI tools for predictive maintenance.
- This means that an increase in MTBF is in the right direction for achieving the best standards for improving the reliability of the equipment.

4.5.2. Enhanced Decision-Making with Real-Time Visualization:

- The web-based Power BI enabled the maintenance teams to access one source of truth that assists in the quick resolution of the issues.
- This translated into more efficient work in the aspect of regulatory compliance reporting which helped to minimize the chances of penalties for non-compliance.

4.5.3. Financial and Operational Impact:

- The above financial implication makes it clear that the use of BI to support maintenance management is cost-effective by tallying to around $ 480000 per year.
- These positive changes encouraged efficient resource provisions, forecast abilities and a decrease in repairing frequency by 33%.

4.5.4. Stakeholder Adoption and Usability:

- Thus, the 90% adoption rate among the maintenance staff indicates that Power BI is useful in increasing the transparency of the workflow.
- The experiences gathered from the user survey reflected that the tool was easy to use and useful for planning maintenance.

4.5.5. Comparison with Prior Research:

These results corroborate the findings from other manufacturing and industries where the BI systems have been implemented and have resulted in similar cost savings of about 20-30% and efficiency gains. By enhancing the body of knowledge, this research establishes that BI integration in pharmaceutical maintenance is possible and has a lot of advantages.

V. Conclusion

This paper also aims to show how the application of efficient BI tools such as Power BI can change the aspect of pharmaceutical maintenance operations. The use of several live data feeds into a dashboard allows the maintenance teams to monitor KPIs as well as trends and improve resource management. The problems that Power BI was able to solve include cutting equipment downtime by one-third, maintenance costs by one-fourth and an increase in MTBF by forty per cent. These outcomes support the statement that the application of predictive analytics, as well as data visualization results, are critical for planning effective maintenance management and preventing failures which disrupt further production.

In addition, this study strengthens the need to invest in BI in industries that require compliance, reliability, and efficiency in their operations. The interactive dashboards also improve the visibility of production operations which enables the maintenance teams and the management to work on probable failures as they occur. By Analyzing the aspects of pharmaceutical maintenance, it is possible to identify the advantages: even so, using the Power BI can bring, for instance, up to $480 000 in annual cost reduction. This paper aims to propose the use of contingency models for integrating data analytics and automation into maintenance workflows of Industries 4.0 in order to remain competitive and compliant with adopted regulative standards.

5.1. Future Work

Therefore, for future research, there are certain areas which have the potential for the enhancement of capabilities of Power BI in pharmaceutical maintenance. The other opportunity to be explored is the connectivity of IoT devices with the Power BI dashboard, where one can monitor the sensors and pre-empt any failure based on an anomaly detected by the sensors with higher accuracy. Moreover, it is also worth using machine learning in the case of predictive maintenance so that the models of failures and their time can be further improved. One more specific area is cross-functional data sharing, where using Power BI the departments of manufacturing, quality, and supply chain can be incorporated into the maintenance system to

provide an organized and vertical approach to their company's management. These enhancements are not only going to allow for better equipment and financial advantages but also rigidity in compliance with drug control and organizational steadfastness in the pharmaceutical sector.

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