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PERFORMANCE PARADOX: HIGH MAINTENANCE EXPECTATIONS VERSUS LOW TECHNOLOGICAL INVESTMENT IN INDUSTRIAL ENTERPRISES

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***Abstract**: This study investigates the current state of maintenance practices, performance evaluation methodologies, and the adoption of digital management systems within industrial organizations in Sibiu County, Romania. The primary objective was to empirically quantify the gap between the perceived strategic importance of maintenance and the practical maturity of its implementation. A quantitative, non-experimental survey design was utilized. Data was collected from a convenience sample of 104 professionals across various industrial sectors, with a significant representation from the automotive industry. The survey instrument assessed organizational demographics, maintenance strategy prevalence (Corrective, Preventive, Predictive), perceived impact on productivity and quality, and the use of specialized management software (CMMS/ERP). Data analysis employed descriptive statistics and cross-tabulations. Results confirmed the high strategic value of maintenance, with over 70% of respondents reporting a strong influence on product quality and productivity. However, the study revealed a significant technological disparity: while Preventive Maintenance (44.2%) was the most common strategy, a substantial portion of organizations (34.6%) reported operating without any specialized CMMS or ERP system for maintenance management. Furthermore, the adoption of advanced Predictive Maintenance was minimal. A critical gap exists between the recognized strategic role of maintenance and the operational maturity of the sector. The lack of integrated digital infrastructure hinders the adoption of advanced, data-driven strategies and limits the ability to accurately measure and benchmark performance through holistic KPIs. Bridging this gap requires strategic investment in both digital systems and specialized personnel training to transition the sector toward truly predictive and efficient maintenance models.*

***Keywords**: Maintenance Performance, Maintenance Strategy, CMMS, ERP, Predictive Maintenance, Performance Measurement, OEE.*

1. INTRODUCTION

The modern industrial landscape, characterized by rapid technological advancement and highly competitive global markets, mandates that organizations maintain maximum operational continuity and asset efficiency (Jardine & Tsang, 2005). Maintenance is no longer viewed merely as a necessary expense but as a strategic function that directly influences productivity, safety, product quality, and cost efficiency (Tsang, 2002). Consequently, the systematic evaluation of Maintenance Performance has emerged as a critical driver of organizational competitiveness (Denes & Grecu, 2024).

In this context, efficient maintenance programs, particularly those focused on preventive and predictive strategies, are essential for extending equipment lifespan, mitigating unplanned downtime, and optimizing operational costs (Mobley, 2008). Industry frameworks such as Total Productive Maintenance (TPM) and the Overall Equipment Effectiveness (OEE) metric exemplify the industry's shift toward holistic, performance-driven maintenance management (Nakajima, 1988). The rigor and precision demanded in high-stakes sectors, such as automotive manufacturing, further underscore the need for effective maintenance performance measurement, as errors can significantly impact large-scale production quality and throughput.

Despite the theoretical and practical recognition of maintenance's strategic role, many organizations continue to struggle with inconsistent performance evaluation and low adoption rates of advanced digital tools (Petruse et al., 2016). While traditional corrective and simple time-based preventive maintenance are widely practiced, the uptake of sophisticated, data-driven strategies—such as Predictive Maintenance (PdM) based on condition monitoring—remains underdeveloped (Pintelon et al., 2006). Furthermore, a significant number of firms still rely on rudimentary tracking methods rather than integrated Computerized Maintenance Management Systems (CMMS) or Enterprise Resource Planning (ERP) tools, limiting their ability to accurately capture, analyze, and benchmark performance across key indicators (Wireman, 2005). Consequently, a gap exists between the recognized strategic importance of maintenance and the practical maturity of performance measurement methodologies employed in many industrial environments.

To address this knowledge gap, the present study investigates the practical application and perceived effectiveness of maintenance performance evaluation methods among industry professionals in the Romanian industrial sector. This research aims to characterize the prevalent maintenance strategies, assess the perceived impact of maintenance on productivity and quality, and examine the current level of adoption of both traditional frameworks (e.g., TPM, OEE) and advanced digital systems (CMMS/ERP).

We utilized a quantitative survey methodology to collect primary data from professionals across multiple industries, with a focus on capturing both organizational profiles and specific performance evaluation practices. The subsequent sections of this paper present a comprehensive theoretical background on maintenance performance, detail the methodology used for the empirical study, discuss the results concerning current practices and technological adoption, and conclude with strategic recommendations for advancing maintenance performance management.

2. THEORETICAL BACKGROUND ON MAINTENANCE AND PERFORMANCE MEASUREMENT

2.1 Introduction and Scope

Maintenance has evolved from a reactive necessity to a strategic function critical for maximizing asset utilization, ensuring quality, and controlling costs (Tsang, 2002). Effective maintenance management requires systematic performance evaluation to align activities with strategic business objectives and drive continuous improvement (Amos et al., 2019). This review synthesizes literature on maintenance strategies, performance measurement frameworks, and the impact of digital technology, establishing the theoretical basis for assessing current industrial practices.

2.2 Evolution of Maintenance Strategies

Maintenance strategies are categorized by their timing relative to equipment failure. Corrective Maintenance (CM), the initial approach, involves repairing assets *after* failure, leading to high costs and unexpected downtime (Ghalayini & Noble, 1996). The shift to Preventive Maintenance (PM) introduced planned interventions, such as Time-Based Maintenance (TBM), to reduce failure probability (Jardine & Tsang, 2005).

Advanced strategies include Condition-Based Maintenance (CBM) and Predictive Maintenance (PdM). CBM monitors physical conditions (e.g., vibration, temperature) to schedule interventions optimally, while PdM uses sophisticated analytics, often incorporating machine learning, to forecast the exact time of impending failure (Al-Najjar et al., 2016; Pintelon et al., 2006). The most holistic approach, Reliability-Centered Maintenance (RCM), is a risk-based framework that determines the optimal mix of strategies for each asset based on the consequences of its failure (Moubray, 2001).

2.3 Performance Measurement and Frameworks

Performance Measurement (PM) quantifies the efficiency and effectiveness of maintenance actions, using Maintenance Performance Indicators (MPIs) such as Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) (Gackowiec, 2019; Ighravwe, 2022; Wireman, 2005). These indicators must be strategically aligned with organizational goals (Kaplan & Norton, 2005).

The Overall Equipment Effectiveness (OEE) is a key composite metric, calculated as the product of Availability, Performance, and Quality. OEE is foundational to continuous improvement philosophies like Total Productive Maintenance (TPM), which seeks to eliminate the *Six Big Losses* by engaging all employees in maximizing equipment efficiency (Nakajima, 1988). Strategically, the Balanced Scorecard (BSC) provides a multi-criteria framework that integrates maintenance performance across financial, customer, internal process, and learning perspectives, mitigating the limitations of purely financial metrics (Kaplan & Norton, 2005).

2.4 Digital Transformation and Managerial Methods

The effectiveness of maintenance performance evaluation hinges on structured managerial methods and technological support (Grecu & Denes, 2024). Total Quality Management (TQM) principles rely on the iterative Plan-Do-Check-Act (PDCA) cycle for systematic process optimization and sustaining improvements (Heizer, 2016; Roşca & Grecu, 2009).

Crucially, digital transformation underpins advanced maintenance. Computerized Maintenance Management Systems (CMMS) and Enterprise Resource Planning (ERP) tools serve as the digital backbone, automating work order management, inventory control, and the critical capture of performance data (Palmer, 2006). Effective utilization of these systems is a prerequisite for transitioning to data-driven PdM strategies and accurate OEE tracking.

2.5 Conclusion of the Literature Review

The literature underscores the consensus that advanced maintenance requires a shift toward predictive, risk-based strategies supported by robust performance frameworks like OEE and managerial philosophies like TPM. However, a significant practical gap is repeatedly noted: the inconsistent adoption of integrated digital systems (CMMS/ERP) necessary for accurate, data-driven performance measurement (Palmer, 2006). While the theoretical benefits of PdM are clear, empirical data on the actual adoption levels of both advanced strategies and supporting digital infrastructure in specific regional contexts is often limited. This study aims to address this gap by empirically assessing the maturity of maintenance practices and performance measurement methodologies within the industrial environment of Sibiu County.

3. METHODOLOGY

3.1 Research Design and Approach

This study utilized a quantitative, non-experimental survey research design to investigate the current state of maintenance practices and performance evaluation methods within industrial organizations. This approach was selected as the most appropriate method for achieving the research objectives, which primarily involved characterizing organizational profiles, identifying the prevalence of maintenance strategies, and measuring the perceived impact and adoption rates of specific tools (e.g., CMMS/ERP, KPIs) across a diverse professional population (Heizer, 2016).

3.2 Sampling Strategy and Data Collection

The sampling strategy employed was a convenience sampling technique, targeting professionals with direct involvement or knowledge of maintenance and operational processes. The target population comprised employees from various industrial sectors, predominantly located in Sibiu County, Romania.

Data were collected using an online self-administered questionnaire developed in Google Forms. The questionnaire was structured to gather specific, quantifiable data related to the study objectives, including:

1. Organizational demographics (industry, company size, respondent department).
2. Maintenance strategy adoption (corrective, preventive, predictive).
3. Impact assessment (influence on productivity and quality, measured on a Likert scale).
4. Performance evaluation methods (use of KPIs, specific monitoring tools).
5. Technology adoption (use of CMMS/ERP systems).

The survey instrument underwent pilot testing with a small group of professionals (N=6) to ensure clarity, relevance, and semantic validity before mass distribution. The final questionnaire included specific control questions to validate data consistency, particularly regarding the reported use of digital systems and monitoring practices. The survey was disseminated via professional networks, email, and social media platforms.

3.3 Sample Size and Data Screening

A total of 157 responses were initially received. Through a screening process based on the consistency of answers to control questions and completeness, 104 responses were deemed valid for inclusion in the final analysis. This sample size (N=104) provided sufficient data volume for meaningful statistical analysis and trend identification.

3.4 Data Analysis

The collected quantitative data were exported from Google Forms and analyzed using the Statistical Package for the Social Sciences (SPSS) software. The primary analytical techniques used included:

1. Descriptive Statistics: Frequency distributions and percentages were calculated to characterize the sample demographics, maintenance practices, and adoption rates of specific tools (e.g., as presented in Tables 1 and 2).

2. Inferential Statistics: Cross-tabulations and correlation testing were used to examine relationships between variables, such as the correlation between CMMS/ERP adoption and the reported use of specific KPIs or evaluation methods.

The analysis focused on identifying prevailing industry trends and validating the perceived alignment between maintenance practices and strategic outcomes (e.g., productivity and quality impact).

3.5 Methodological Limitations

This study acknowledges several methodological limitations. The use of convenience sampling limits the generalizability of the findings, as the sample is not necessarily representative of the entire national industrial context, particularly given the high representation from the automotive sector. Furthermore, the reliance on self-reported data introduces the possibility of response bias, where participants may overestimate the formality or effectiveness of their maintenance practices. Finally, as a cross-sectional study, it captures performance at a single point in time and cannot establish longitudinal causality between the observed practices and subsequent performance improvements. These limitations were mitigated by including consistency checks in the questionnaire and focusing the analysis on descriptive trends rather than complex causal modeling.

4. RESULTS

The analysis of the valid survey responses (N=104) focused on characterizing the participating organizations, identifying maintenance strategies and performance evaluation practices, and quantifying the perceived impact of maintenance on operational outcomes.

4.1 Respondent and Organizational Profile

The respondent pool was primarily drawn from large industrial organizations. Specifically, 39.4% of participants reported working in firms with over 250 employees. Small companies (10–49 employees) represented 27.9% of the sample, while medium-sized enterprises (50–249 employees) accounted for 25.0%.

The sectoral distribution of the participating organizations revealed a strong concentration in the automotive manufacturing sector. Nearly half (49.0%) of the responses originated from the Automotive Industry, highlighting the critical role maintenance plays in this high-reliability sector. The Food Industry accounted for 13.5% of the sample, with the remaining 37.5% distributed across other diverse industrial sectors.

Professionals from IT/Support departments constituted the largest respondent group (20.2%), followed by Production (15.4%), Quality (14.4%), and Maintenance (13.5%). Furthermore, a high proportion of respondents held higher education degrees, with 40.4% possessing a Bachelor’s degree and 31.0% holding a Master’s degree.

4.2 Maintenance Strategies Employed

The organizations reported using various maintenance strategies. Preventive Maintenance was the most prevalent approach, cited by 44.2% of respondents. Corrective Maintenance was the second most common strategy, utilized by 38.5% of the organizations. The adoption of Predictive Maintenance (PdM) was minimal, suggesting that these advanced condition-based methods were not widely utilized in the surveyed population.

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4.3 Perceived Impact on Productivity and Quality

Respondents overwhelmingly recognized the strategic value of maintenance. Figure 1 illustrates the high perceived influence of maintenance on operational outcomes and contrasts this with the reported usage of digital evaluation tools.

In terms of perceived influence, 68.3% of respondents reported a high or very high impact on organizational productivity. Similarly, the combined percentage of respondents indicating a strong influence on product or service quality ("to a large extent" and "to a very large extent") reached 71.1%.

However, the findings also revealed a significant gap in digital maturity. While 54.8% of organizations reported using CMMS/ERP systems for generating maintenance reports and analyses, a substantial portion of the sample, 34.6%, reported using no specialized CMMS or ERP system for maintenance management, indicating a reliance on manual or non-integrated data tracking methods.

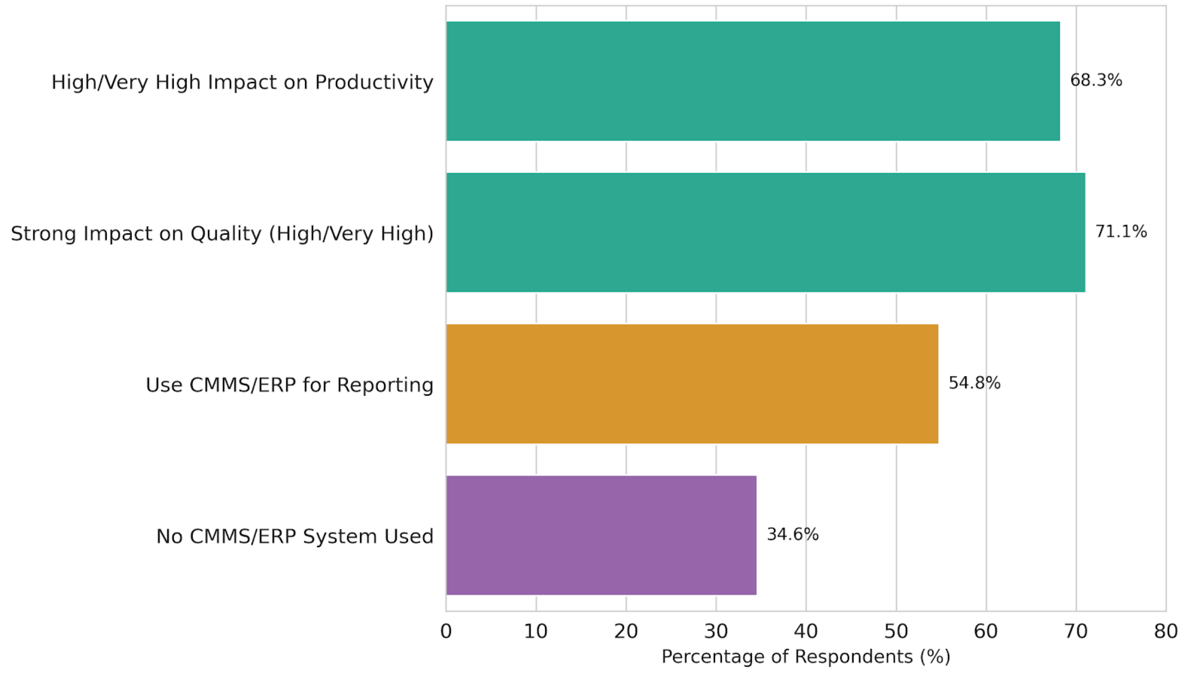

Figure 1. Perceived Maintenance Impact and Digital System Use (N=104)

4.4 Performance Evaluation and Technology Adoption

A total of 68.3% of organizations reported using specific Key Performance Indicators (KPIs) to evaluate maintenance efficiency. Other reported evaluation methods included periodic audits (55.8%) and the analysis of maintenance costs (42.3%).

Monitoring practices focused on a combination of historical comparisons and system-generated reports, as detailed in Table 1.

Method Used for Evaluating Maintenance Performance	Percentage of Organizations (%)
Comparing equipment performance before and after maintenance	61.5%
Reports and analyses generated by CMMS/ERP systems	54.8%

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Monitoring of downtime (unplanned stops)	40.0%
Analysis of maintenance costs	29.8%

Table 1. Prevalence of Maintenance Performance Evaluation Methods (Multiple Selections Allowed)

Technology adoption for maintenance management was notably incomplete. 34.6% of the surveyed organizations reported using no specialized CMMS or ERP system specifically for managing their maintenance activities. Of those who did utilize digital systems, 54.8% relied on the reports and analyses generated by these CMMS/ERP systems for performance evaluation.

4.5 Suggested Improvement Measures

When asked to identify the most effective measures for improving maintenance activities, respondents prioritized technological advancement and training. The most frequent suggestions were:

1. Use of modern equipment and technology (59.6% of responses).
2. Increasing the proportion of Predictive Maintenance activities (55.8% of responses).
3. Periodic and systematic training of maintenance personnel and operators (51.9% of responses).

5. DISCUSSION

5.1 Interpretation of Major Findings

The results of this study underscore the strategic imperative of maintenance in the industrial sector, particularly within the context of Sibiu County. The finding that over two-thirds of respondents perceive maintenance as having a high or very high influence on both productivity (68.3%) and quality (71.1%) directly supports the theoretical perspectives advanced by Tsang (2002) and Mobley (2008), which conceptualize maintenance as a core value-adding function rather than a cost center. This validates the rationale for organizations to invest in robust performance measurement systems.

The study also revealed that Preventive Maintenance (PM) remains the dominant strategy (44.2%), closely followed by Corrective Maintenance (CM) (38.5%). This prevalence of traditional strategies is consistent with findings in regional and developing industrial contexts where time-based scheduling is favored for its simplicity and established methodology (Pintelon et al., 2006). However, the minimal adoption of Predictive Maintenance (PdM) highlights a significant gap in technological maturity. This reliance on scheduled or reactive models indicates that many firms have yet to fully embrace the predictive capabilities necessary to achieve optimal equipment utilization and cost efficiency, as advocated by Al-Najjar et al. (2016).

5.2 Digital Maturity and Performance Measurement Inconsistencies

A critical finding is the low adoption rate of specialized maintenance management systems: 34.6% of organizations reported using no CMMS or ERP system for maintenance tracking. This presents a contradiction with the finding that 68.3% of firms reported using Key Performance Indicators (KPIs) and 54.8% rely on system-generated reports for evaluation.

This discrepancy suggests two possibilities: first, that performance measurement, even where KPIs are utilized, may be inconsistent, non-integrated, and reliant on manual tracking rather than real-time data capture; second, that the reported "system-generated reports" may stem from basic spreadsheet software or generic ERP modules not specialized for maintenance, limiting comprehensive data analysis (Palmer, 2006). Without a robust CMMS/ERP platform, effective calculation and tracking of complex, leading indicators such as Overall Equipment Effectiveness (OEE) or true MTBF becomes highly challenging, undermining efforts toward Total Productive Maintenance (TPM) (Nakajima, 1988). The most popular evaluation method, comparing performance before and after maintenance (61.5%), reinforces this retrospective, rather than predictive, approach to performance assessment.

5.3 Comparison with Existing Literature and Contextual Significance

The high representation of the Automotive Industry (49.0%) suggests that the strong focus on quality and productivity in the sample is heavily influenced by the rigorous standards imposed by this sector. Automotive supply chains typically mandate adherence to continuous improvement models (like TQM and TPM), which may explain the high *perceived* importance of maintenance.

The finding that the top three suggested improvements involve technology adoption (modern equipment, 59.6%) and increasing PdM (55.8%) demonstrates that professionals are aware of the need to bridge the technology gap identified in the literature (Pintelon et al., 2006). The prioritization of training (51.9%) aligns with the Learning & Growth perspective of the Balanced Scorecard (Kaplan & Norton, 2005), recognizing that human capability is essential for successful technological implementation.

5.4 Limitations and Future Research Directions

The results must be interpreted in light of the study's limitations. The convenience sampling focused on Sibiu County and its high concentration of automotive firms means the findings may not be fully generalizable to the national industrial average. Furthermore, the reliance on self-reported data could lead to an inflation of reported KPI usage or quality perception (response bias).

Future research should address these limitations by:

1. Conducting comparative studies across different regions and industrial sectors to determine if the digital adoption gap is a regional or sectoral phenomenon.
2. Implementing longitudinal case studies in firms that successfully adopt CMMS/ERP systems to objectively measure the resulting impact on OEE, MTBF, and maintenance costs, validating the return on investment for digital transformation.
3. Investigating the specific barriers (financial, cultural, skill-based) that prevent organizations with recognized KPI usage from implementing PdM and dedicated CMMS/ERP systems.

6. CONCLUSION

This research aimed to empirically evaluate the prevailing maintenance strategies and the maturity of performance evaluation methods within industrial organizations in Sibiu County. The findings confirm the core argument that maintenance is widely perceived as a strategic function directly driving both organizational productivity and product quality, aligning with established management theory (Tsang, 2002).

Our study revealed a critical disparity between the high strategic perceived value of maintenance and the low technological maturity of its implementation. While most firms engage in scheduled Preventive Maintenance, the continued high reliance on Corrective Maintenance and the minimal adoption of advanced Predictive Maintenance (PdM) strategies signify that the industry is still operating at a foundational level, often failing to harness the true potential of proactive, condition-based maintenance (Pintelon et al., 2006).

The most significant finding concerns the digital adoption gap: a considerable percentage of organizations operate without a specialized CMMS or ERP system for maintenance management. This absence of an integrated digital backbone severely limits the ability of firms to accurately track KPIs, calculate holistic metrics like OEE, and implement the data-driven continuous improvement cycles inherent in philosophies like TPM (Nakajima, 1988). Effectively, the lack of digital infrastructure prevents organizations from transitioning from simply measuring *what happened* to proactively predicting *what will happen*.

In conclusion, while industrial organizations recognize that maintenance is vital, the current practices are largely retrospective and lack the necessary digital infrastructure to transition to a truly strategic, predictive model. To bridge this gap, the most crucial next steps, as identified by the professionals themselves, involve a simultaneous investment in modern technology, increased PdM activities, and systematic personnel training. These findings provide clear recommendations for industrial management: the next phase of operational excellence depends not just on recognizing maintenance's importance, but on making the strategic commitment to digital transformation and advanced performance analytics.

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