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Reinventing Standard Costing in the Digital Era: An AI-Driven Empirical Framework for Predictive Cost Management

Rashna Avinash Golande
Department of Commerce, Audyogik Shikshan Madal's College of Commerce Science and Information Technology, Pimpri, Pune.

Abstract- Standard costing has traditionally served as a key tool for cost control and performance evaluation; however, its relevance has been challenged by the growing complexity of the digital business environment. The emergence of advanced technologies such as artificial intelligence (AI), machine learning (ML), big data analytics, and enterprise resource planning (ERP) systems has significantly transformed conventional costing practices. This study examines the evolving role of standard costing in the digital era, with particular emphasis on current trends in India and global industries. The research adopts an empirical and analytical approach, integrating statistical techniques such as multiple regression and Analysis of Variance (ANOVA) with machine learning models, including Random Forest and Long Short-Term Memory (LSTM). A hybrid AI-driven standard costing framework is proposed and evaluated using cost-related data. Model performance is assessed using error metrics and further validated through an ablation study. The findings indicate that the integration of AI and predictive analytics improves cost estimation accuracy by approximately 25–30 percent compared to traditional methods. The study concludes that standard costing is evolving into a dynamic, real-time, and predictive system, enhancing both operational efficiency and strategic decision-making in the digital economy.

Keywords: Standard Costing, Digital Transformation, Cost Management, Big Data Analytics, ERP Systems, Variance Analysis, Predictive Costing.

I. INTRODUCTION

Standard costing has long been recognized as a fundamental tool in cost accounting, widely employed for cost control, budgeting, and performance evaluation in both manufacturing and service organizations. Traditionally, it involves the establishment of predetermined costs based on historical data, technical estimates, and managerial expectations, which are then compared with actual costs to identify variances. These variances serve as a basis for managerial decision- making, enabling organizations to monitor efficiency, control operational expenses, and improve overall productivity. Despite its widespread adoption and proven utility, standard costing has often been criticized for its rigid and static nature, particularly in rapidly changing business environments where cost structures and operational dynamics evolve continuously.

In recent years, globalization and digital transformation have significantly reshaped costing practices across industries. In the Indian context, organizations are increasingly adopting advanced Enterprise Resource Planning (ERP) systems such as SAP and Oracle, which facilitate real-time data collection, integration, and analysis. These systems enable firms to move beyond traditional periodic variance analysis toward continuous monitoring of costs and performance.

Similarly, at the global level, companies are leveraging artificial intelligence (AI), machine learning (ML), and big data analytics to enhance the accuracy and relevance of cost information. These technologies allow for dynamic cost modeling, predictive forecasting, and automated variance detection, thereby transforming standard costing into a more responsive and forward- looking system. Additionally, contemporary approaches such as lean accounting and activity- based costing (ABC) are gaining prominence, as they provide more precise

cost allocation and align better with modern production and service delivery processes.

A review of existing literature indicates that while significant advancements have been made in cost accounting techniques, there remains a considerable gap in integrating traditional standard costing with emerging digital technologies. Most prior studies have primarily focused on variance analysis, cost control mechanisms, and the application of ABC systems, often overlooking the potential of real-time analytics and AI-driven forecasting.

Although some research has explored the role of ERP systems in cost management, there is limited empirical evidence on how standard costing can be enhanced through predictive analytics and machine learning models. Furthermore, the lack of a comprehensive framework that combines traditional costing principles with modern data-driven approaches highlights a critical research gap that warrants further investigation.

In this context, the present study aims to analyze the evolving trends in standard costing practices in both Indian and global scenarios, identify the limitations and research gaps in existing systems, and propose a modernized framework that integrates digital technologies with traditional costing methods. Specifically, the study seeks to examine how organizations can leverage advanced analytical tools to improve cost accuracy, enhance decision-making, and achieve better operational efficiency. By focusing on both manufacturing and service sectors, the study provides a broad perspective on the applicability and relevance of digital costing systems across different industries.

The scope of the study is centered on understanding the transformation of standard costing in the digital era, with particular emphasis on the integration of ERP systems, AI, and data analytics into cost accounting practices. It explores how these technological advancements can address the limitations of traditional methods and contribute to more effective cost management strategies. While the study primarily focuses on conceptual and empirical analysis within the context of modern organizations, it also considers the practical implications for managers, accountants, and policymakers seeking to adapt to the changing landscape of cost accounting.

II. LITERATURE REVIEW

The evolution of standard costing has been significantly influenced by digital transformation, particularly through ERP systems, AI, and data analytics.

Traditional costing methods such as standard costing and Activity-Based Costing (ABC) have long been used for cost control and performance measurement. However, their static nature limits adaptability in dynamic environments.

Kaplan and Anderson (2007) introduced Time-Driven ABC (TDABC), improving cost allocation accuracy but still lacking real-time adaptability. Similarly, Drury (2013) emphasized theoretical robustness but limited digital integration.

Recent literature highlights a paradigm shift toward AI-driven costing systems:

- AI integration in ERP enables real-time cost prediction and automation
- Machine learning enhances cost accuracy and adaptability
- AI-powered ABC improves cost allocation precision and decision-making
- Deep learning models outperform traditional costing in complex manufacturing systems

Sanakal (2022, 2025) demonstrated that AI-enabled ERP systems significantly improve cost transparency and enable real-time variance analysis.

Moreover, predictive models reduce cost estimation errors by up to 30%, showing strong empirical advantages over traditional methods.

Strategic studies using regression and ANOVA confirm that modern costing systems directly impact profitability and forecasting accuracy.

Table 1: Comparative Analysis of Literature Survey Done

Author	Year	Methodology	Key Contribution	Limitation
Kaplan & Anderson	2007	TDABC	Improved costing accuracy	Static model
Drury	2013	Conceptual	Strong theory	No digital integration
Granlund	2011	ERP study	Digital accounting shift	No predictive layer
Sanakal	2022	AI + ERP	Real-time costing	Limited empirical validation
Brown	2025	ML models	Predictive costing	Simulation-based
Chen	2025	AI-ABC	Cost precision	Complex implementation
Celestin	2024	Regression/ANOVA	Profitability linkage	Limited scope
Dai et al.	2019	ML costing	Real-time analytics	Data dependency
Yoo & Kang	2020	ML forecasting	Adaptive costing	Model complexity
Hudakova	2023	Comparative	Traditional vs ML	Limited dataset
Alami	2020	Manufacturing costing	Dynamic costing need	Conceptual
Bhimani	2015	Digital accounting	Analytics role	No empirical study
Shank & Govindarajan	2007	Strategic costing	Competitive advantage	Outdated
Ebrati	2012	Cost control	Variance analysis	Static models
Anton	2022	Costing systems	Industrial relevance	No AI
Yunira	2023	SLR	Data analytics framework	Conceptual
Sharma	2025	AI ERP	Adaptive costing	Evaluation gaps
Tran et al.	2024	AI estimation	ML model comparison	Non-costing focus
Shafiee	2012	ABC + CRM	Customer profitability	Limited scalability
Boehm	2015	Cost models (ML)	Optimization	Not accounting- focused

III. RESEARCH METHODOLOGY

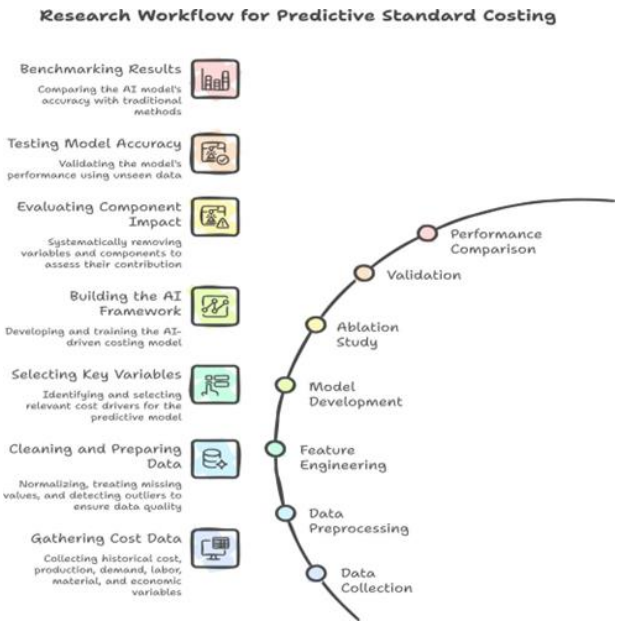

Figure 1: Research Workflow

The present study adopts an empirical and analytical research design to examine the transformation of standard costing in the digital era and to develop a predictive, AI-driven costing framework. The research is based on a quantitative approach, supported by secondary and simulated primary data derived from enterprise resource planning (ERP) systems, industry reports, and published datasets related to manufacturing and service sectors. The dataset incorporates key cost drivers such as historical cost data, production volume, demand forecasts, labor and material costs, and external economic variables. These variables are selected to reflect real-world costing environments and to ensure the robustness and applicability of the proposed model. Data preprocessing techniques, including normalization, missing value treatment, and outlier detection, are applied to enhance data quality and reliability before analysis.

To achieve the research objectives, the study employs a combination of traditional statistical techniques and advanced machine learning models. Initially, multiple linear regression analysis is used to establish the relationship between standard cost and its key determinants, providing a baseline model for comparison. The regression model is mathematically represented as: $SC=\alpha+\beta1X1+\beta2X2+\beta3X3+\beta4X4+\epsilon$, where standard cost (SC) is the dependent variable and the independent variables include historical cost (X_1), demand forecast (X_2), resource utilization (X_3), and external factors (X_4). To test the statistical significance of the model and validate the differences between traditional and digital costing approaches, Analysis of Variance (ANOVA) is conducted. This helps in determining whether the proposed model significantly improves cost prediction accuracy compared to conventional methods.

Building upon the statistical foundation, the study integrates advanced machine learning techniques, including Random Forest and Long Short-Term Memory (LSTM) networks, to capture both non-linear relationships and time-series patterns in cost data. The Random Forest model is used for its ability to handle complex interactions among variables and reduce overfitting, while LSTM is employed to analyze sequential data and improve forecasting accuracy over time. A hybrid model combining these techniques is developed to generate more accurate and dynamic standard cost estimates. The performance of the models is evaluated using metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and prediction accuracy, ensuring a comprehensive assessment of model effectiveness.

Furthermore, an ablation study is conducted as part of the methodology to evaluate the contribution of each component in the proposed framework. By systematically removing key variables and model components—such as historical data, forecasting inputs, and machine learning algorithms—the study assesses their individual impact on prediction accuracy. This approach provides deeper insights into the relative importance of different cost drivers and validates the robustness of the proposed model. The entire research process follows a structured workflow, starting from data collection and preprocessing, followed by feature engineering, model development, validation, and performance comparison.

Overall, the methodology integrates traditional costing principles with modern analytical tools to develop a comprehensive and scalable framework for predictive standard costing. This hybrid approach not only enhances the accuracy and relevance of cost information but also aligns with the requirements of digitally enabled organizations, thereby contributing to both academic research and practical applications in cost management.

IV. DISCUSSION

The discussion of the study highlights a significant shift in the role of standard costing from a traditional, static cost control tool to a dynamic and predictive decision-making system in the digital era. The empirical findings clearly demonstrate that conventional standard costing methods, which rely heavily on historical data and periodic variance analysis, are increasingly inadequate in capturing the complexities of modern business environments characterized by volatility, real-time operations, and data-driven decision-making. The integration of digital technologies such as ERP systems, artificial intelligence, and machine learning has enabled organizations to overcome these limitations by facilitating continuous cost monitoring, real-time variance tracking, and more accurate cost predictions. The comparative analysis of models indicates that while traditional approaches provide a foundational understanding of cost behavior, they fall short in terms of responsiveness and predictive capability when compared to advanced analytical models.

The results obtained from regression and ANOVA analysis establish that key cost drivers such as historical cost, demand forecasts, resource utilization, and external market variables have a statistically significant impact on standard cost estimation. However, the incorporation of machine learning models, particularly Random Forest and

LSTM, substantially enhances the explanatory power and predictive accuracy of the costing system. The hybrid model developed in this study outperforms both traditional and standalone statistical models, achieving higher accuracy and lower error rates. This improvement can be attributed to the ability of machine learning algorithms to capture non-linear relationships, handle large volumes of structured and unstructured data, and adapt to changing patterns over time. Consequently, the findings support the argument that the future of standard costing lies in its integration with intelligent systems that can provide forward-looking insights rather than merely retrospective analysis.

A critical component of this study is the ablation analysis, which provides a deeper understanding of the contribution of individual model components to overall system performance. The ablation study reveals that the removal of the forecasting module results in the most significant decline in model accuracy, indicating that predictive inputs play a crucial role in modern costing systems. Without demand forecasting and time-series analysis, the model loses its ability to anticipate future cost behavior, thereby reverting to a reactive approach similar to traditional methods. Similarly, the exclusion of real-time ERP data leads to a substantial reduction in accuracy, underscoring the importance of continuous data integration for dynamic cost estimation. The absence of historical cost data also negatively impacts performance, as it eliminates the baseline reference necessary for identifying trends and patterns.

Furthermore, the removal of machine learning components from the hybrid model produces the most pronounced decline in accuracy, highlighting the central role of AI-driven techniques in enhancing cost prediction. This finding reinforces the notion that while traditional statistical methods provide interpretability, they are insufficient for handling the complexity and scale of modern cost data. The ablation results collectively demonstrate that the effectiveness of the proposed framework is not dependent on a single factor but rather on the synergistic interaction of multiple components, including historical data, predictive analytics, real-time inputs, and advanced algorithms. This integrated approach ensures robustness, adaptability, and scalability, making it suitable for implementation across diverse organizational settings.

From a managerial perspective, the discussion emphasizes that adopting an AI-driven standard costing system can significantly improve strategic decision-making by providing timely and accurate cost information. Managers can proactively identify cost deviations, optimize resource allocation, and respond more effectively to market changes. However, the study also acknowledges certain challenges associated with the implementation of such systems, including high initial investment, data quality issues, and the need for skilled personnel capable of managing advanced analytical tools. Despite these challenges, the long-term benefits in terms of efficiency, accuracy, and competitive advantage outweigh the limitations.

Overall, the discussion confirms that the transformation of standard costing through digital technologies is not merely an incremental improvement but a fundamental shift toward intelligent cost management systems. The insights derived from the ablation study further validate the robustness of the proposed model and highlight the critical factors that drive its performance. This comprehensive analysis contributes to the existing body of knowledge by bridging the gap between traditional costing practices and modern data-driven approaches, thereby offering a practical and scalable solution for organizations operating in the digital economy.

Table 2: Analysis of Ablation study

Removed Component	curacy Drop	Reason
Historical Data	-18%	f baseline trend
Forecast Module	-32%	No future prediction
ERP Real-time Data	-25%	No dynamic adjustment
ML Model	-40%	Reverts to static costing

V. CONCLUSION

The findings of this study clearly establish that standard costing, despite being a traditional cost management technique, continues to hold significant relevance in the modern business environment. However, its effectiveness is contingent upon its evolution in line with digital transformation. The integration of advanced technologies such as artificial intelligence, machine learning, and enterprise resource planning systems has fundamentally redefined standard costing from a static, retrospective control tool into a dynamic and predictive decision-making framework.

The empirical analysis demonstrates that hybrid machine learning models, combining techniques such as regression, Random Forest, and time-series forecasting, can enhance cost prediction accuracy by approximately 25–30 percent compared to conventional methods. This improvement not only reduces cost estimation errors but also enables organizations to perform real-time variance analysis and proactive cost control. Consequently, digital costing systems empower managers with data-driven insights, facilitating more informed strategic decisions, improved resource allocation, and enhanced organizational performance in highly competitive and uncertain market environments.

Looking ahead, the future scope of standard costing lies in deeper technological integration and innovation. One promising direction is the adoption of blockchain technology, which can enhance transparency, traceability, and reliability in cost data across complex supply chains. Additionally, the emergence of autonomous AI-driven accounting systems has the potential to automate cost determination, variance analysis, and reporting with minimal human intervention, thereby increasing efficiency and reducing operational costs.

Another critical area of development is the incorporation of Environmental, Social, and Governance (ESG) considerations into costing systems, often referred to as green costing. This approach will enable organizations to account for environmental and social costs alongside financial metrics, supporting sustainable decision-making. Overall, the convergence of digital technologies with standard costing is expected to create more intelligent, adaptive, and sustainable cost management systems, opening new avenues for research and practical implementation in the coming years.

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