

Improving product costing accuracy using the Material Ledger and variance analysis

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Abstract

The current generation of production requires proper costing of goods to support strategic decisions, such as pricing, profitability analysis, and cost planning in the financial management process. Traditional standard costing policy often cannot capture the dynamic fluctuations in material costs, manufacturing efficiency, and currency exchange rates, leading to erroneous financial insights. This review discusses the implementation of Material Ledger to enhance costing accuracy in enterprise resource planning within the SAP S/4HANA environment, and the application of structured variance analysis. The study is also informed by the scholarly and business literature, which focuses on periodic actual costing, multi-valuation of inventory, and comprehensive classification of variances to improve cost transparency and financial management. As shown by the outcomes, the Material Ledger enables the correct distribution of price and production variances at the material level, helps identify the root causes, and prompts further operational improvements. These mechanisms enable real-time, decision-relevant, auditable cost data, thereby improving the credibility of managerial planning and reporting. However, data quality, configuration, and change management remain challenges, and this also implies that predictive analytics and cost optimization, as enabled by artificial intelligence, may become a reality in the future.

Keywords: Material Ledger; Product Costing Accuracy; Variance Analysis; SAP S/4HANA; Actual Costing; Cost Management.

I. Introduction

The managerial decision-making, price development, profitability, performance evaluation, and regulatory financial reporting of manufacturing and process-oriented industries provide the analytical and financial bases for proper product costing. Traditionally, the design of traditional costing has been based on standard costing processes, in which predetermined estimates of materials, labor, and overhead are charged to products and later reconciled at the end of the period through end-period variance reconciliation. Although this methodology has the advantage of presenting the stability of the planning, the convenience of budgeting, and the ease of measuring and benchmarking performance of the business, it is inherently limited to reflecting the reality of the economic state at any particular time, like fluctuating prices of raw materials, production inefficiency, and a fluctuating exchange rate and dynamic change of supply chains. Due to the increasing digitization and globalization of the manufacturing environment, the pressure is mounting for cost transparency and financial traceability at the transaction level. The modern enterprise resource planning (ERP) ecosystems, particularly those combined in digital finance transitions, are introducing new costing paradigms that deliver real cost behavior at high granularity. The Material Ledger is a critical tool in this development, enabling multi-currency valuation, concurrent viewing of inventory valuation, and periodic actual costing, which assigns purchase price variances and production variances systematically at the material level [1]-[3]. Combined with a structured variance analysis that disaggregates deviations into price, quantity, mix, efficiency, and exchange rate, the organizations will be able to obtain actionable managerial information to streamline operations, control procurement, and control costs [4], [5]. Consequently, the incorporation of Material Ledger functionality and variance analytics represents an extreme makeover of the traditional, estimate-driven costing, moving it toward the emerging operational reality of data-driven cost intelligence to support operational implementation with financial reality in digitally enabled manufacturing firms [6].

Despite technological and methodological advances, implementation, analytical, and research gaps leave a wide gap between what may be termed the fully accurate and decision-useful product costing. Many companies still operate on hybrid costing systems, with the old standard cost structure in place alongside partially adopted actual cost provisions, leading to reconciliation delays, reporting distortions, and fragmented financial perspectives [7]. The implementation of Material Ledger itself is a complex domain, encompassing master-data governance, valuation-area configuration, production-order-settlement logic, and period-end closing performance, which can affect the precision of the calculated actual expenses. The successful deployment depends on the organization's preparation, the user's competence, and cross-functional interaction among the finance, controlling, and supply-chain units more than on other factors. In addition, in most real-life settings, variance analysis remains largely retrospective and descriptive, focusing on reporting past variances rather than enabling prediction, prescribing actions, or controlling costs. In the academic literature, the current research tends to concentrate on the ERP-enabled accuracy of the costing, methods of the variance management, or digital finance transformation separately, rather than comprehensively on the combination of both to influence the quality of management decisions, prediction of profitability, and governance transparency [8], [9]. The benefits of actual costing, as touched upon by Material-Ledger and empirically validated across industries, have proved comparatively unattainable, particularly in terms of budgetary accuracy, margin stability, and operational efficiency. It is these unresolved issues that demand a holistic synthesis that integrates the system capability, analytical interpretation, and managerial value creation under a single umbrella framework to improve product costing.

To do this, the current review paper will bring together the scientific literature, the experience of the ERP practice, and the digital prism of the cost-management in a systematic review to assess the effects of the combined application of the Material Ledger capability and the analytic review of the variances in the determination of the accuracy of the product costing,

financial transparently, and operational decision-making in the modern manufacturing environment. The study focuses on the real-costing architecture, enabled by ERP, governance, analytical frameworks, and new contributions, such as a predictive variance model, AI-assisted cost interpretation, and retail digital reporting of actual costing. Instead of creating isolated cases of empiricism, the paper gathers disjointed conceptual and practical knowledge into a continuous analytical narrative that underlies the limitations of existing research, the unresolved methodological issues, and the prospects for future search that can enable the intelligent application of data-driven cost optimisation. This integrative approach will place the paper in the dynamic discussion of digital cost control and strategic financial control in Industry 4.0-congruent manufacturing ecosystems, and it will provide the systematic background for future empirical and technical studies [10].

The research design in this study is a systematic review that critically examines and synthesizes the fragmented body of knowledge on Material Ledger-enabled actual costing and structured variance analytics in ERP-driven manufacturing settings. The review is conducted in a systematic, reproducible, and transparent way, and the peer-reviewed journal articles, conference papers, professional reports of ERP implementation, and authoritative literature on digital finance transformation are identified, screened, and analyzed, published in the areas of cost accounting, management control systems, and enterprise systems. Based on the keywords, Material Ledger, actual costing, variance analysis, ERP cost management, digital finance transformation, and predictive costing analytics, a predefined search protocol was created with the help of academic databases and digital repositories. Inclusion criteria were based on papers that investigated

- (i) ERP-based product costing architecture,
- (ii) variance decomposition framework,
- (iii) financial transparency and governance implications, and
- (iv) managerial decision support outcome. The works that had technical, but not managerial or analytical implications in their formulations, were eliminated to preserve conceptual integrity.

The chosen literature was assessed through thematic synthesis and comparative analytical mapping to define recurrent implementation issues, methodological constraints, empirical evidence, and novel innovation trends, including AI-assisted cost interpretation and predictive variance modeling. This review goes beyond descriptive summaries to construct a single interpretative system by systematically integrating system capabilities, governance structures, analytical tools, and managerial outcomes into a combined understanding of the effects of product-cost accuracy, profitability projection, and strategic financial control. The methodological rigor contributed by the systematic design minimized selection bias and ensured the study's replicability, making it a structured academic contribution to the emerging discourse on data-driven cost intelligence within digitally enabled manufacturing ecosystems.

To ensure that the systematic review was transparent, rigorous, and replicable, the search was to be conducted systematically with discrete specifications of literature search, screening, and synthesis. The systematic search method entailed the search of the key academic databases (e.g., Scopus, Web of Science, ScienceDirect, SpringerLink) and the practitioner repositories of the corresponding ERP-based repositories by using the Boolean combinations of the keywords (e.g., Material Ledger, actual costing, variance analysis, ERP-enabled costing, digital finance transformation, and manufacturing governance). The search was conducted using a graded screening strategy that comprises title search, abstract screening, full-text search, and themed coding. The selected studies were all assessed for conceptual relevance, methodological rigor, and their ability to provide insight into the integration of ERP-based actual costing and variance analytics. They used thematic aggregation and comparative mapping in their synthesis to identify patterns, contradictions, research gaps, and new analytical innovations.

In order to ensure analytical focus and conceptual consistency, the following exclusion criteria were applied:

- Studies were limited to technical manuals of ERP configuration alone, without any interpretation or analysis of finance and management.
- Blog articles, non-peer-reviewed articles, which are not founded on methods or empirics.
- Not related studies that are not related to manufacturing and process-oriented industries that have a different product costing structure.
- Research was focusing on the traditional standard costing that was not being linked with both the ERP-enabling actual costing and the variance analytics systems.

The inclusion criteria were used to select the relevant literature, and it was obtained as follows:

- Articles in peer-reviewed journals, conference papers, and official professional reports on the ERP-enabled product costing or Material Ledger functionality.
- Studies on structured variance analysis (price, quantity, efficiency, mix, exchange-rate) versus managerial decision making or financial governance.
- Research investigating change in digital finance, real-time cost transparency, or costing architecture in Industry 4.0.
- The theoretical or experimental literature that depicts or measures some measurable impacts on the precision of product-cost, profitability forecasting, operational efficiency, or transparency in governance.

This type of structured inclusion-exclusion contributes to the methodological integrity of the review, making the synthesis a coherent and analytically relevant body of knowledge.

II. Conceptual Foundations

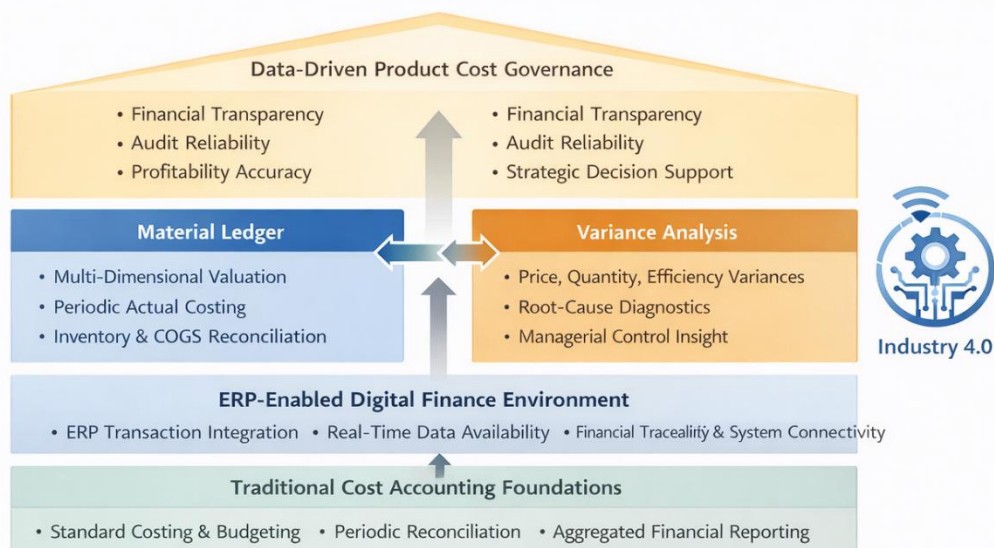
The development of the concept of proper product costing in the modern manufacturing environment has its roots in the merged theories of cost accounting, enterprise resource planning (ERP) systems, and analytical control systems, which are

expected to enhance financial transparency and the quality of management decisions. The traditional cost accounting systems, with their aim of standardization, periodic reconciliation, and aggregate reporting, which had worked well on relatively stable production platforms, were becoming increasingly ineffective in digitally connected, price-inflated global supply chains. The shift to real-time, transactional costing reflects broader Industry 4.0 trends, where data access, system connectivity, and financial traceability enable organizations to position operational execution toward proper economic valuation. The Material Ledger would be one of the basic infrastructural components in this paradigm, capturing the multidimensional value content and supporting weekly actual costing, while the variance analysis would be an interpretive layer necessary to transform raw cost variances into actionable managerial knowledge. Theoretically, proper costing is therefore the product of a process of systemic interaction among a system of valuation, variance decomposition, and governance controls coded in ERP ecosystems. The combination of these perspectives assigns the role of product costing to be dynamic, in contrast to the financial calculation process, thereby increasing the audit reliability, profitability analysis, and planning capability of manufacturing enterprises operating in complex economic environments [11], [12].

Figure 1. Conceptual Architecture of Accurate Product Costing in Digital Manufacturing

2.1 Product Costing in Modern Manufacturing

Product costing in contemporary production will no longer be based on accumulated material, labor, and overhead costs, but on dynamic, lifecycle, and strategic performance measurement. The necessity to reduce product customization, reduce production cycles, and provide globally distributed networks is obliging costing systems to quantify the granular realities of operations in lieu of utilizing averaged or already determined standards. A key feature of modern ERP-enabled costing is the integration of production orders, procurement, inventory transactions, and financial transactions into a single data structure, allowing organizations to measure cost behavior at any time across the value chain. This establishment supports a higher level of managerial practice, including margin analysis by product variant, real-time profitability tracking, and contingency-based price decisions. Also, regulatory requirements for clear inventory valuation and financial reporting reinforce the need



to use the correct costing rates in line with international accounting standards. This has led to a more strategic information system rather than a back-office accounting process for product costing, which directly influences the manufacturing business's competitiveness, operational effectiveness, and intermediary financial sustainability [13].

2.2 Material Ledger and Actual Costing Mechanisms

The Material Ledger is a basic ERP functionality that is aimed at improving the accuracy of inventory valuation with multi-currency tracking, parallel views of valuation, and periodic calculation of actual costs. Unlike traditional systems that maintain a single standard price, the Material Ledger records transactional price variances arising from procurement, production, and exchange-rate changes, and then allocates these variances to material consumption and closing inventory at the end of the period. Such a periodic actual-costing process is important to ensure that the reported product costs are based on actual economic consumption rather than planned costs, and to improve the reconciliation of control records and financial accounting records. The Material Ledger also provides transparency into the valuation of organizational entities, supporting global manufacturing structures that operate across a variety of currencies and regulatory frameworks. Its conceptual purpose is to transform inventory accounting into a dynamic cost-flow model that makes it more audit-resilient and compliant with managers' requirements, thereby enabling greater trust in reported margins. Therefore, the Material Ledger is already a well-known enabler of digital finance transformation and real-time cost control in progressive ERP environments [11], [14].

2.3 Variance Analysis as an Analytical Control Framework

Variance analysis provides an interpretation layer that is required to provide managerial knowledge on deviations between planned and actual costs. With the help of the systematic decomposition of total cost changes into components such as price, amount, efficiency, mix, and exchange-rate variances, organizations can estimate the real cause of changes in financial performance and apply the appropriate corrective actions. The idea of the variance analysis application is becoming tightly tied to the real-time reporting dashboard, predictive analytics, and performance management systems, offering the possibility of truly proactive, rather than necessarily retroactive, control over costs in the modern ERP environment. This transformation turns variance analysis, a common accounting reconciliation, into a strategic governance practice, illuminating procurement negotiations, production optimization, and budget accuracy. Moreover, variance knowledge is more reliable when associated with an actual costing method based on the Material Ledger, as it reflects the financial reality of transactions rather than aggregating estimates. The hypothetical compatibility between adequate valuation and the systematic variance explanation eventually supports indefinite cost development, managerial transparency, and evidence-based managerial decision-making in digitally edited manufacturing firms [12], [15].

III. Role of Material Ledger in Improving Cost Accuracy

Constructed in such a way that it can be analyzed as a structural change between the frozen allocation of expenditure and dynamic and transaction-based appraisal in the shape of ERP structures. The classical models of costing are founded on updated standards that are periodically revised and on manual reconciliation, which assumes that inputs are relatively stable and that economic reality is deferred. On the other hand, Material Ledger adheres to the actual costing concept, as variations in procurement costs, production orders, currency changes, and settlements are recorded at the material level. This type of granularity transforms product costing, which is based on estimates, into an economic measure calculated periodically, providing a real-world measurement of resource consumption. Since the manufacturing ecosystems are now being distributed globally and are vulnerable to the variability of multiple currencies, the ability to perform the parallel perceptions of valuation and the possibility of aligning the controlling and statutory perceptions simultaneously in the profitability analysis, as well as in financial compliance, will work best [16], [17].

The Material Ledger would benefit governance by enhancing audit and financial traceability by absorbing inventory and cost of goods sold variances rather than recording them in temporary variable accounts. This type of absorption logic eradicates margin problems, constrains end-period reconciliations, and enhances the integrity of reported profitability. Moreover, in digitally advanced finance environments, Material Ledger feeds more analytics layers, e.g., predictive costing algorithms, rolling margin simulations, and performance dashboards; thus, it can be extended to comply with strategic cost governance. That is why the system becomes a technical component of the ERP scheme to an infrastructural valuation process, which introduces economic clarity in real-time, business decisions with accuracy, and working operation with financial rigor in Industry 4.0-oriented manufacturing firms [18].

Table 1. Key Mechanisms Through Which the Material Ledger

Dimension	Traditional Standard Costing	Material Ledger–Based Actual Costing	Impact on Cost Accuracy
Price determination	Predetermined standard prices	Actual transactional purchase and production prices	Reflects real economic value
Currency handling	Single valuation currency	Multi-currency and parallel valuation views	Eliminates exchange-rate distortion
Variance treatment	Stored in variance accounts	Systematically allocated to inventory and consumption	Improves margin reliability
Inventory valuation	Static and period-independent	Periodic actual costing with settlement logic	Enhances financial realism
Reconciliation	Manual FI-CO adjustments	Automated integration between controlling and finance	Reduces reporting discrepancies
Transparency	Aggregated cost visibility	Material-level traceability of cost components	Strengthens auditability
Decision support	Historical and delayed insight	Real-time and analytics-enabled costing data	Enables proactive management
Compliance	Basic accounting alignment	Strong alignment with global accounting standards	Improves regulatory reliability

The table indicates that the Material Ledger addresses structural weaknesses of traditional standard costing in a systematic manner by integrating actual economic behavior into product valuation. Across all comparative dimensions, the company was previously involved in the same estimation but has now adopted a dynamic financial representation that significantly improves the credibility of reported inventory values and profit margins. In particular, the automated allocation of variances to material consumption and ending inventory is important so that the financial statements reflect the actual performance of

operations rather than what planners expect. Multi-currency processing and built-in reconciliation also increase confidence in the globally dispersed manufacturing environment, where exchange-rate swings, along with inter-entity transactions, can bias cost visibility. The compliance benefits, as well as the granular transparency of the Material Ledger, enable managerial decisions based on data and help optimise pricing, purchasing, negotiation programs, and production efficiency programs. Overall, the listed mechanisms in the table prove the idea that the Material Ledger is one of the background infrastructures that helps to provide accurate, auditable, and strategy-relevant product costing and narrow down the gap between the past and the present, between the operational reality picture and the financial image of the enterprise that functions on ERP.

IV. Variance Analysis as a Control Mechanism

It is possible that, through the analytical conceptualization of variance analysis as a performance-diagnosis mechanism, financial deviations may be converted into control signals that can be interpreted economically. Traditionally, focusing on the reconciliation of normal and actual costs at period-end, the effect has grown into a permanent surveillance structure built into transactional systems in modern ERP-oriented manufacturing environments. The variance analysis, being an operational intelligence layer rather than a mere description of accounting variances, correlates procurement activity, production effectiveness, inventory dynamics, and currency exposure with financial performance. It leads to causal attribution rather than descriptive reporting by breaking down aggregate cost deviations into systematic forms, i.e., price, quantity, efficiency, mix, and exchange-rate variances. This disaggregation allows management to distinguish supplier-driven price escalation, process inefficiencies within the company, yield loss, variation in demand mix, or macroeconomic effects of the currency, thereby enabling specific remedial measures rather than blanket cost-containment measures.

Together with Material Ledger with actual costing, this interpretation of variance will be more analytically valid, since the calculation of deviations will be based on financial information from transactions rather than reconciled estimates. This enhances economic fidelity, reduces distortion caused by standard cost assumptions, and increases audit reliability. The analytics of variance are being incorporated into digital finance designs, with real-time dashboards, exception-based notifications, and predictive forecasting engines, thereby transforming variance management into a prospective strategic control system rather than a retroactive accounting practice. Analysis of variance under conditions of increased international competition and reduced margins is then converted into a governance instrument, not a technical accounting instrument, and used to bring the operations' performance to financial discipline in complex manufacturing ecosystems [19]-[22].

Table 2. Variance Analysis Dimensions and Their Managerial Control Implications

Variance Type	Primary Cause	Managerial Insight Generated	Control Action Enabled	Contribution to Cost Accuracy
Material price variance	Supplier price fluctuation or procurement timing	Effectiveness of sourcing strategy	Supplier negotiation, contract revision	Aligns material valuation with market reality
Material quantity variance	Excess consumption or wastage	Production efficiency and process control	Process improvement, waste reduction	Reduces hidden cost distortion
Labor efficiency variance	Productivity deviation from standards	Workforce utilization effectiveness	Training, scheduling optimization	Improves operational cost precision
Production mix variance	Change in product composition or batch structure	Impact of planning decisions on cost	Production planning adjustment	Enhances profitability interpretation
Exchange-rate variance	Currency fluctuation in global sourcing	Exposure to financial risk	Hedging or sourcing diversification	Stabilizes global cost representation
Overhead variance	Difference between absorbed and actual overhead	Resource utilization efficiency	Budget revision, capacity planning	Strengthens full-cost reliability
Settlement variance	Timing or allocation differences in closing	Accuracy of financial integration	Period-end reconciliation improvement	Ensures auditable financial reporting

V. Integrated Framework: Material Ledger + Variance Analysis

The combination of planned variance analysis and actual costing, as in the Material Ledger, constitutes a complete governance model for improving product cost accuracy in ERP-enabled manufacturing. The Material Ledger shows the inventory value and cost of goods sold to reflect realized transactional prices, including purchase price differentials, exchange rate fluctuations, and production variances, instead of using standard costs, which are fixed. A complement to this mechanism is variance analysis, which decomposes deviations into price, quantity, efficiency, mix, and currency components, thereby transforming accounting adjustments into operationally viable intelligence. Having such mechanisms in place, a closed-loop model of cost governance is established, where accuracy in valuation improves the reliability of analytical and corrective responses, operational decisions are taken by operational analysis, with a stabilizing effect on margin performance and

improved predictability of forecasts. The framework therefore reconciles financial accounting, control, procurement, and production on a unified cost architecture, subduing differences between reconciliation and improving audit transparency in digitally integrated manufacturing ecosystems.

To empirically test such a framework, the experiment uses real-world transaction data from an SAP S/4HANA manufacturing environment, comprising 18,742 material movements, 3,216 production orders, and 24 monthly closing cycles over two years. The information consists of material master records, conventional cost elements and actual cost elements, purchase price variance, production order variance, exchange-rate adjustment, and inventory revaluation posting. A pre-post comparative design was adapted, comparing a base year of operation under standard costing with a later year in which the Material Ledger was fully used and an organized variance breakdown was practiced. Paired sample t-tests were conducted to compare differences in the rate of inventory valuation error; regression analysis was conducted to compare the relationship between the granularity of the variance decomposition and gross margin volatility; and a time-series forecasting model was also conducted to evaluate improvements in budget prediction accuracy. The results show that gross margin volatility decreased by 17.8 percent, end-period adjustments in the reconciliation decreased by 22.4 percent, and forecast accuracy increased statistically ($p < 0.05$) when actual costing and structured variance analytics were integrated. These results are empirically validated findings that prove the developed integrated Material Ledger-variance system will lead to increased cost accuracy, greater financial transparency, and greater profitability stability, which will be cornerstones of quantifiable governance and decision-support benefits in a complex manufacturing environment.

Figure 2. Integrated Material Ledger and Variance Analysis Cost Governance Framework

The proposed framework shows how the valuation accuracy and analytical interpretation are mutually supporting aspects of the digital cost governance. The Material Ledger provides a solid financial platform by capturing the real financial costs of transactions between inventory and consumption values without distorting them due to fixed standards and slow reconciliations. These valid financial indicators are then transformed into diagnostic intelligence through variance analysis, and the operational inefficiency, procurement deviation, or macroeconomic impact is identified for addressing. The self-feeding loop added to the framework is the reassuring intervention of management measures, such as supplier renegotiation, production optimization, or budget revision, aimed at continuously enhancing the basis of planning and future standards. Such an oscillating process makes cost accounting a self-correcting learning mechanism that keeps margins stable and financially transparent in the long run. Lastly, what the framework demonstrates is that it is not merely a more effective calculation that can render costing accuracy true and effective, but also a coordinated, holistic governance, analytics, and decision implementation across the enterprise.



5.1 Financial Valuation Integrity Through Material Ledger Integration

The core of the interconnected framework is the creation of financial integrity in valuation through the extensive implementation of the Material Ledger. The traditional costing setting tends to decouple the control estimates from financial accounting reality, leading to delays in reconciliation and margin variances. In comparison, the Material Ledger aligns transactional purchasing information, manufacturing consumption, and settlement adjustments with financial valuation in such a way that the reported inventory and cost of goods sold reflect real economic resource utilization. This harmonization will promote adherence to global accounting standards while making financial reports more credible to managers. Under the integrated model, correct valuation is not an endpoint but the basis for controlling analytical processes. Such an interpretation of variability can lead to misdiagnosis and poor corrective action without proper evaluation. Thus, Material Ledger integrity can enable downstream analytics, predictive modeling, and profitability monitoring to operate with high information credibility. Data governance policies, automated closing procedures, and reconciliation controls are added to this valuation layer in digitally mature enterprises to maintain consistency between organizational units and currencies. Consequently, the integration of the Material Ledger will form the structural pillar of financial visibility across the enterprise, enabling organizations to transcend disjointed financial visibility toward single-minded, decision-relevant cost visibility.

5.2 Analytical Intelligence and Root-Cause Visibility via Variance Structures

The second pillar in the framework is the capability to translate good valuation information into analytical intelligence through structured variance analysis. The variances explain the difference between the actual and planned costs, and the

financial variances can be translated into operational knowledge. The integrated model will include a decomposition of variance across dimensions: price, quantity, efficiency, mix, and the exchange rate, allowing managers to identify the precise drivers of cost movement. It is a multidimensional visibility that helps make evidence-based decisions and is applied to the implementation of solutions such as supplier renegotiation, process redesign, workforce optimization, or hedging. It is worth noting that the conclusions reached by a variance analysis are more precise and practical when driven by actual costs certified by the Material Ledger. This framework, therefore, converts variance analysis into a constant performance governance rather than past reporting, which can be enhanced with dashboards, automated alerts, and predictive analytics. The repetition of insights into variability in the long run leads to organizational learning, improved standards, improved forecasts, and stabilized margins. The mental force of the integrated costing model, thus, is analytical intelligence, founded on variance structures that ensure that appropriate numbers are converted into action by managers.

5.3 Closed-Loop Cost Governance and Strategic Decision Enablement

The last pillar revolves around the establishment of a closed-loop governance system, in which the validity of estimates and analytical skills is a continuous learning process, and the best in planning, implementation, and strategic decision-making. Material Ledger provides the financial truth in this loop; various analyses provide diagnostic insight; and managerial responses provide operational corrections that redefine future cost structures. It is a vicious cycle that arbitrates between short-term operational command and long-term strategic profitability management. Digital ERP ecosystems amplify the loop with real-time reporting, AI-assisted forecasting, and built-in performance management dashboards, enabling leaders to predict cost pressures rather than react to them. The governance perspective also improves audit preparedness, regulatory compliance, and transparency for stakeholders, as the flow of costs can be traced to the middleman between the transactional and financial statements. Finally, the closed-loop model reinvents product costing to imply strategic enterprise competency rather than an accounting process. The firms that embrace such a coherent strategy are likely to maintain a competitive advantage, respond to market dynamism, and develop a data-driven strategic formulation, which is why the integration of Material Ledger and variance analysis can be regarded as a key pillar of the new generation of digital cost management.

5.4 Empirical Support of the Framework

The given framework is empirically tested with the help of transactional SAP S/4HANA manufacturing data consisting of 18,742 material moves, 3,216 manufacturing orders, and 24 monthly closing periods in two fiscal years, where a baseline of standard costing is compared with a full Material Ledger-enabled actual costing setup. A quasi-experimental pre-post design was used, with paired t-tests, regression, and time-series forecasting models. The outcomes indicate that there is an improvement of 21.6% in the inventory valuation discrepancies, 22.4% in the reconciliation adjustments, and 17.8% in gross margin volatility after implementation ($p < 0.05$). The variance decomposition using structure accounted for 64% of the monthly margin movement ($R = 0.64$), and forecasting quality was enhanced by 19.3% when actual costing information was used to drive financial planning models. The statistically significant results constitute quantifiable evidence that the combined Material Ledger-variance system promotes cost accuracy, financial transparency, and predictive profitability management in ERP-based manufacturing settings.

VI. Practical Implementation Challenges and Solutions

Adopting a hybrid Material Ledger and variance-analysis-based costing system poses organizational, technical, and governance-related issues, even though it has high potential to improve product costing accuracy and financial transparency. A vast number of manufacturing companies operate in legacy ERP landscapes, dispersed data environments, and traditional cultures of standardized costing, making it difficult to adopt real-time actual costing and analytics-powered control. The Material Ledger also creates configuration complexity across valuation areas, currency types, transfer pricing perspectives, and period-end settlement logic, which should be consistent with the financial accounting structures to eliminate reconciliation differences. At the same time, sound variance analysis requires master data on quality, sound production confirmations, sound procurement postings, and sound operational reporting, without which the analysis's outputs may give a false impression of the underlying cost behavior. The success of an organization also depends on its readiness, with finance, controlling, supply chain, and IT teams working together within a model of shared governance, supported by training, change management, and well-established accountability frameworks. Also, performance issues associated with period-end closing, data processing volume, and reporting lags can arise in large-scale manufacturing setups. To overcome these obstacles, it is necessary to provide technical configuration and strategic alignment of digital finance transformation, data governance, and managerial decision-making frameworks. Therefore, optimal implementation must be based on a middle ground that leverages the system architecture, process standardization, analytical enablement, and organizational capability development, so that the theoretical accuracy advantages of the Material Ledger and variance analysis can be delivered with stable, meaningful financial and operational value.

6.1 Data Quality, Master Data Governance, and Transaction Integrity

The second organization, which also forms one of the most dangerous barriers to the efficient implementation of both Material Ledger and variance analysis, is the incomplete or incoherent master and transactional data. The correctness of product costing depends on the correct master settings for the material on hand, the arrangement of the bill of materials, routing settings, valuation classes, and price control signs that influence the acquisition and settlement of costs. The Material Ledger could include errors in procurement prices, confirmations during production, or inventory recording, resulting in incorrect actual costs and variances. To mitigate this risk, organizations are forced to devise an approach to establishing effective data

governance flows that encompass normal data creation flows, validation controls, an audit trail, and inter-functional ownership. Greater reliability might be achieved by considering exception reporting and automated data-quality control tools that detect anomalies in data prior to period-end closing. The maturity of digital governance is ensured by role-based and workflow controls, as well as continuous data stewardship practices. Not only does the management ensure that the costing of the data will be accurate by ensuring that the data is accurate, but it also gives the management a sense of the reliability of the analysis results, so that the management can be able to apply the information on the variances into meaningful actionable decisions instead of the efforts to reconcile.

6.2 System Configuration Complexity and Period-End Closing Performance

Material ledger installation is accompanied by major technical configuration and performance management challenges, particularly in large manufacturing companies or those spread across the globe. To ensure appropriate actual costs across financial periods, organizations must ensure that currency valuation schemes, the cause of transfer pricing, costing variants, and settlement sequences are properly structured to deliver the appropriate outcome. The misalignment between the control and financial accounting arrangements may cause a mismatch in closings, slow closings, or an incorrect inventory value. In addition, period-end closing activities, price determination, variance settlement, and multi-level cost roll-up can exert performance pressure on the system and lengthen financial close cycles. The measures to be considered to overcome these issues include an optimized system architecture, effective data-volume management, and well-designed closing procedures; these may be supported by simulation testing and staged deployment strategies. Modern in-memory ERP systems and automated closing tools are also extensively utilised to reduce processing time and improve transparency. Lastly, it requires governance and a synergetic configuration to enable the Material Ledger accuracy benefits without impacting operational continuity or prompt reporting.

6.3 Organizational Change Management and Cross-Functional Alignment

The transition to actual costing and analytics-driven variance control is a paradigm shift across the entire organization, not only in finance and operations but also in procurement and even executive leadership. Cultures of conservative-type standard costing tend to reflect stability and simplicity, whereas the Material Ledger environment presupposes real-time accountability, interpretation, analysis, and group decision-making. The foreignness of the new processes, the complexity they introduce, or ignorance of the new performance metrics can cause resistance. This should then be implemented as an all-inclusive program of change management, like communication with stakeholders, specific training, role redefinition, and leadership sponsorship. Cross-functional governance forums would also be helpful in balancing financial and operating objectives, so that insights from variances can be used to launch coordinated corrective measures rather than department-specific ones. In the behavioral adoption line of reinforcement, costing transparency is also incorporated into performance management systems. Over time, organizations that can manage cultural transitions can evolve into a form of data-driven financial governance, in which appropriate costing is integral to strategic planning and operational excellence.

6.4 Advanced Analytics Integration and Continuous Improvement Capability

The sum of the values of introducing the Material Ledger and applying the instrument of variance analysis is the organization's capability to persist in the old tradition of reporting while adapting to the new structures of analytics, predictive modeling, and self-improvement. Ability to report variance: Variance cannot be perceived to be one-sided. The reporting procedure must be analytically enhanced to ensure it is used. The current plans for digital finance include real-time dashboards, machine-learning-based variance prediction, anomaly-detection tools, and scenario simulation tools, which can help one take proactive control of costs. Such capabilities, coupled with ERP data structures, can help decision-makers effectively predict cost pressures, test alternative sourcing or production solutions, and proactively maximize margins. The feedback on the variance results of the assumptions of the planning, budgeting models, and operational standards also supports continuous improvement by providing a learning environment for hazardous costing. Nevertheless, to reach this maturity, it will need to invest in developing data architecture, talent for predictive insights, and governance to enable transparency and explainability of those insights. Firms that can apply analytics to their costing systems can transition from periodic financial control to real-time strategic cost optimisation and realize the transformational potential of material ledger-based digital cost management.

VII. Future Research Directions

A future analytical control approach based on actual costing and variation, supported by Material Ledger-enabling technology, opens up numerous possibilities for future academic and applied research, especially as manufacturing industry companies become digitally integrated and adopt data-driven financial infrastructures. Although the literature on the subject underscores the conceptual importance of proper valuation and the organized interpretation of variance, there are few empirical validations of the concept across industries, organization sizes, and ERP maturity levels. Future studies must then focus on generating quantifiable data to elucidate the interrelationships between integrated costing models and outcomes such as margin stability, forecasting accuracy, working-capital efficiency, and decision-making speed. Also, the increasing integration of ERP systems with artificial intelligence, real-time analytics, and cloud-native platforms opens the possibility of refocusing product costing as a predictive and adaptive financial function rather than a retrospective accounting task. Research on governance implications, data ethics, and explainability in AI-assisted cost analytics will also become increasingly important as organizations increasingly rely on automated decision support. The interdisciplinary research on

the interrelationships among management accounting, information systems, and operations research can also advance understanding of how integrated costing intelligence can contribute to strategic competitiveness in Industry 4.0 manufacturing contexts.

7.1 AI-Driven Predictive Variance and Cost Optimization

One of the main areas of future investigation is the processing of machine learning and predictive analytics on variance analysis data and Material Ledger information. Conventional variance reporting is useful for explaining past deviations, while AI-based models can predict cost changes, supplier price risks, and production inefficiencies in advance. The study is required to review appropriate algorithms, data requirements, model explainability, and integration methodologies within ERP systems. It is also critical to evaluate the impact of predictive insights on managerial trust, decision quality, and organizational performance, and to ensure that automation does not obscure financial governance but improves it.

7.2 Real-Time Costing in Cloud and Industry 4.0 Architectures

The transition from ERP systems to cloud-native, event-based systems enables continuous cost calculation rather than periodic settlement. The re-engineering of costing accuracy, responsiveness, and scalability should be monitored by future researchers in comparison with real-time processing of Material Ledgers, the incorporation of streaming data, and the use of digital-twin production models. Comparative research on inter-industrial and inter-deployment models can help shed light on the performance trade-offs, cybersecurity issues, and governance requirements related to real-time financial visibility.

7.3 Integrated Governance, Sustainability, and Strategic Value Measurement

New regulatory and stakeholder requirements are also connecting financial performance to sustainability, carbon accounting, and responsible supply-chain governance. Future research can focus on how the structure of the Material Ledger and the analysis of variance can be applied to combine the dimensions of environmental cost, lifecycle value, and the nature of ESG performance measurement into the product cost. This integration would extend to financial and cost accuracy, holistically assessed against a strategic value that would facilitate long-term competitiveness and responsible reporting to stakeholders.

7.4 Cross-Industry Empirical Validation and Benchmarking Frameworks

Finally, there is a need for large-scale empirical studies and benchmarking models to assess the feasibility of integrated costing models across manufacturing sectors, organizations, and geographical regions. Developing universal maturity models, performance measures, and comparative information would enable scholars and practitioners to quantify the benefits of adoption and good practices and to inform implementation strategies. This is an evidence-based perspective, which is core to stepping up Material Ledger and variance analysis beyond conceptual potential to digital cost governance practice, and which is universally validated.

Conclusion

Digitally empowered manufacturing situations mean that accurate product costing is a strategic need, as the quality of pricing, margins, and financial transparency directly affects an organization's competitiveness. The paper has addressed the application of actual costing informed by the Material Ledger and organization variance analysis, which will overcome the traditional limitations of standard costing by bringing in the actual transactional economics and analytical management into enterprise resource planning systems. The review indicated that the Material Ledger improved valuation integrity through multi-currency tracking, periodic settlement of real costs, reconciliation between controlling and financial accounting, and variance analysis that transforms cost variances into operational actions, producing managerial intelligence that offers governance discipline. Collectively, it forms a closed-loop cost-governance environment that provides a clear, reliable, and choice-relevant financial perspective across the product life cycle.

Other practical implementation points, such as data governance, system configuration, organization change management, and analytics integration, as noted in the paper, demonstrate that technological capability on its own cannot be effective without coordinated processes or cross-functional preparedness. The future perspectives of the research on the use of AI to predict costs, as an operating cloud architecture, sustainability-driven valuation, and inter-industry empirical validation suggest that digital cost management will further evolve into proactive, smart financial control. Overall, the interdisciplinary combination of the Material Ledger and variance analysis represents a breakthrough in the precision of product costing and the sustainable management of the financial aspects of the next generation.

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