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IMPROVING INTEGRATED MANAGEMENT OF INDUSTRIAL ENTERPRISES THROUGH ERP SYSTEMS: A DYNAMIC INVENTORY CONTROL AND AI-ASSISTED DECISION SUPPORT FRAMEWORK

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Abstract. This study proposes an organizational and economic framework for improving ERP-based integrated management in industrial enterprises, with particular emphasis on Uzbekistan's machinery manufacturing sector. It examines opportunities to enhance the integration of information systems, strengthen coordination among procurement, warehousing, and production operations, and improve the adaptability of conventional static inventory management policies. The proposed framework combines the integration of existing Enterprise Resource Planning (ERP) functions, multi-model bills of materials (BOMs), feedback from Manufacturing Execution Systems (MES), dynamic calculations of safety stock and reorder points, and artificial intelligence (AI)-assisted decision support under human supervision. An economic optimization model incorporates inventory holding costs, procurement costs, material shortage costs, and costs associated with production interruptions. Static and dynamic inventory management policies are compared using operational and economic performance indicators. The study presents a conceptual framework and an analytical evaluation methodology; empirical validation at the enterprise level requires actual production, inventory, and procurement data.

Keywords: Enterprise Resource Planning (ERP), ERP integration, dynamic inventory control, safety stock, reorder point, artificial intelligence (AI), decision support systems, bill of materials (BOM), Manufacturing Execution System (MES), Uzbekistan.

Аннотация. В исследовании предложена организационно-экономическая модель совершенствования интегрированного управления промышленными предприятиями на основе ERP-систем с особым акцентом на машиностроительную отрасль Узбекистана. Рассматриваются возможности повышения степени интеграции информационных систем, укрепления координации процессов закупок, складского хозяйства и производства, а также совершенствования адаптивности традиционных статических методов управления запасами. Предлагаемая модель объединяет интеграцию существующих функций систем планирования ресурсов предприятия (ERP), многовариантные спецификации материалов (BOM), обратную связь с системами оперативного управления производством (MES), динамический расчёт страховых запасов и точек повторного заказа, а также поддержку принятия решений с использованием искусственного интеллекта (ИИ) при сохранении контроля со стороны человека. Экономическая оптимизационная модель учитывает затраты на хранение запасов, закупки, дефицит материалов и перерывы в производственном процессе. Статическая и динамическая политики управления запасами сопоставляются на основе операционных и экономических показателей эффективности. В исследовании представлены концептуальная модель и методика аналитической оценки; для эмпирической проверки на уровне предприятия необходимы фактические данные о производстве, запасах и закупках.

Ключевые слова: планирование ресурсов предприятия (ERP), интеграция ERP-систем, динамическое управление запасами, страховой запас, точка повторного заказа, искусственный интеллект (ИИ), системы поддержки принятия решений, спецификация материалов (BOM), система оперативного управления производством (MES), Узбекистан.

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INTRODUCTION

Digital transformation contributes to enhancing the operational efficiency, competitiveness, and adaptability of industrial enterprises. However, the realization of these benefits depends not only on the implementation of Enterprise Resource Planning (ERP) software but also on the effective integration of information flows across procurement, inventory management, production, sales, and accounting processes (Matt et al., 2023; Schlemitz & Mezhuyev, 2024).

In Uzbekistan, industrial digitalization is supported by the Digital Uzbekistan–2030 Strategy, approved by Presidential Decree No. PF-6079 in 2020[1]. Machinery manufacturing enterprises operate within complex assembly-based production environments in which the timely availability of components is essential for maintaining production continuity. Accordingly, effective inventory coordination can help minimize production interruptions associated with component shortages while reducing storage costs and optimizing working capital requirements.

Conventional inventory management policies based on fixed reorder points and safety stock levels may become less responsive to changes in demand, supplier lead times, and production schedules. Although ERP systems provide a technological foundation for integrating business processes, further opportunities exist to strengthen the interoperability of existing system functions, align inventory decisions with actual production requirements, and incorporate transparent and accountable AI-assisted recommendations into managerial decision-making.

Research Objective. The objective of this study is to develop an integrated management framework that combines a function-preserving ERP architecture, multi-model bills of materials (BOMs), feedback from Manufacturing Execution Systems (MES), adaptive inventory control, and human-supervised AI-assisted decision support, together with a methodology for evaluating the economic performance of the proposed framework.

Scientific Contribution. The study proposes an organizational and economic framework for integrating existing technologies and management methods rather than developing fundamentally new ERP architectures, inventory optimization algorithms, or artificial intelligence models. Its contribution lies in the coordinated application of these components to support integrated management and economically informed inventory decisions in industrial enterprises.

LITERATURE REVIEW

Recent studies emphasize the importance of technological integration, organizational readiness, and measurable performance outcomes in the digital transformation of industrial enterprises. Matt et al. (2023) examine the drivers and barriers associated with digital transformation, while Schlemitz and Mezhuyev (2024) highlight the importance of data standardization and interoperability in smart manufacturing environments [4-5].

Walter et al. (2025) review applications of artificial intelligence in supply chain demand planning, whereas Ilieva et al. (2025) and Abilakimova et al. (2025) examine industrial digitalization and the organizational conditions required for its effective implementation [2-3, 6]. Collectively, these studies indicate that AI-assisted inventory management should be assessed using clearly defined performance indicators, including forecasting accuracy, service levels, inventory-related costs, and managerial accountability.

Building on these research directions, the present study proposes an integrated organizational and economic framework adapted to the characteristics of Uzbekistan's machinery manufacturing sector. The effectiveness of the proposed framework, including its potential application at the Tashkent Tractor Plant, requires empirical validation using transaction-level operational data and clearly defined economic performance indicators [2-6].

RESEARCH METHODOLOGY

The study employs an integrated methodological approach combining systems analysis, process modeling, inventory control methods, predictive analytics, and comparative economic evaluation.

Function-Preserving ERP Integration. Existing accounting, warehouse management, and production management functions are retained where appropriate, while standardized interfaces are used to synchronize transactions across the relevant systems. A unified master data model ensures the consistent identification of materials, suppliers, warehouses, products, and production orders. Data integrity and information security are supported through the use of timestamps, unique transaction identifiers, data validation and reconciliation procedures, and role-based access controls.

1 https://lex.uz/docs/-5030957

Statement on the Use of Artificial Intelligence

Approximately 10% of the manuscript preparation involved the use of artificial intelligence (AI) tools exclusively for language editing, grammatical correction, stylistic refinement, and technical formatting. AI tools were not used to generate research data, conduct empirical analyses, develop scientific findings, or formulate the study's conclusions. The author retains full responsibility for the originality, accuracy, scientific integrity, and final content of the manuscript (Figure 1).

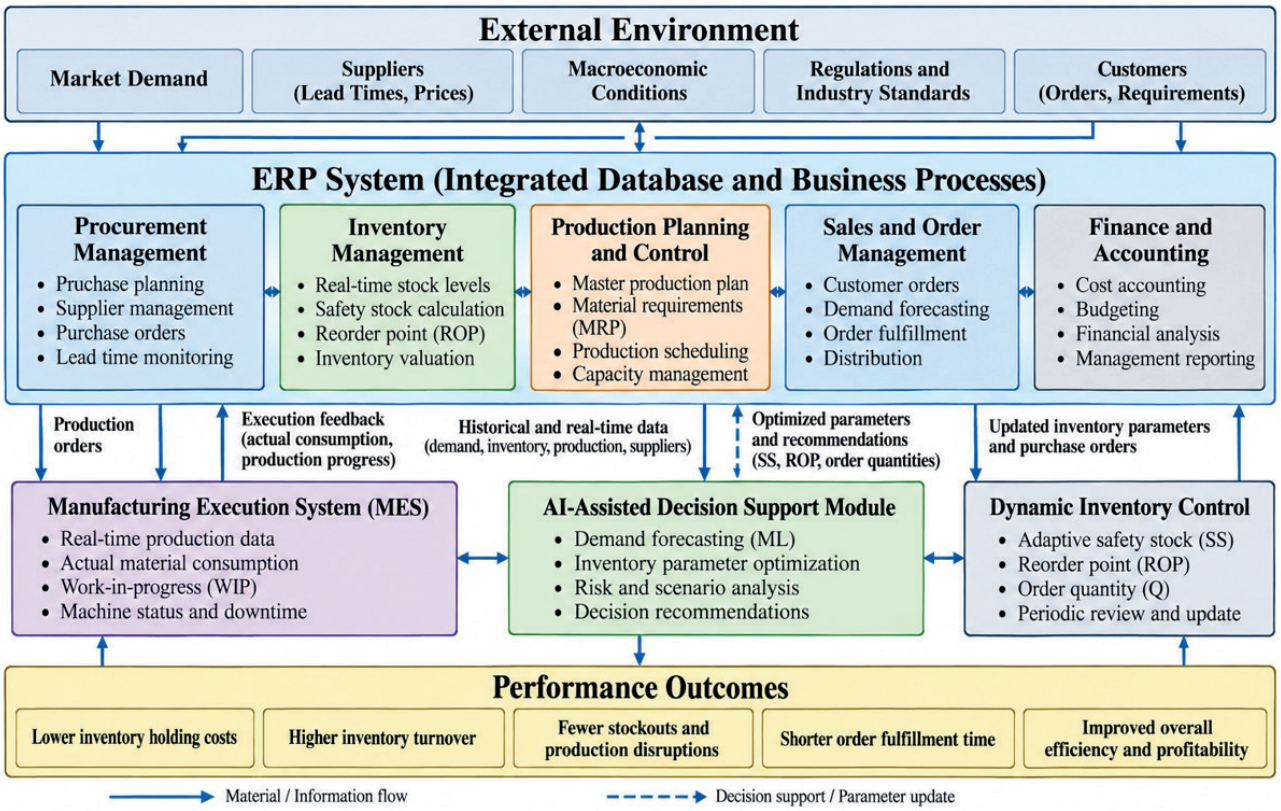


Figure 1. Conceptual Framework of ERP-Based Integrated Management with Dynamic Inventory Control and AI-Assisted Decision Support for Industrial Enterprises[2]

Multi-model BOM. Gross component requirements are calculated as:

$$GR_{i,t} = \sum_{m=1}^{M} B_{i,m} P_{m,t} \quad (1)$$

where B(i,m) is the quantity of component i required for product model m and P(m,t) is planned output. Net requirements are:

$$NR_{i,t} = \max\left(0, GR_{i,t} + SS_{i,t} - I_{i,t} - SR_{i,t}\right) \quad (2)$$

where SS is target safety stock, I usable inventory and SR scheduled receipts. Reservations, scrap, substitutes and BOM versions must be considered in implementation.

MES feedback. Deviations between actual and planned material consumption are:

$$\Delta Q_{i,t} = Q_{i,t}^{\text{actual}} - Q_{i,t}^{\text{planned}} \quad (3)$$

These deviations inform inventory reconciliation, BOM accuracy and production-loss analysis.

Dynamic safety stock and reorder point. Under simplifying independent demand and lead-time uncertainty assumptions:

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$$SS_{i,t} = z_{\alpha}\sqrt{\hat{L}_{i,t}\sigma^2_{d,i,t} + \hat{d}^2_{i,t}\sigma^2_{L,i,t}} \quad (4)$$

$$ROP_{i,t} = \hat{d}_{i,t}\hat{L}_{i,t} + SS_{i,t} \quad (5)$$

where $\hat{d}_{i,t}$ is expected daily demand, $\hat{L}_{i,t}$ expected lead time, $\sigma_{d,i,t}$ and $\sigma_{L,i,t}$ their standard deviations, and $z_{(\alpha)}$ the service-level coefficient. Correlated or intermittent demand requires other estimation methods.

AI-assisted recommendations. Continuous demand forecasts may use regression; shortage-risk classification may compare logistic regression, Random Forest and Gradient Boosting. Validation uses time-aware splits and appropriate metrics (MAE/RMSE/WAPE for forecasts; precision/recall/F1/ROC-AUC for classification). Recommendations are subject to economic evaluation and human approval.

ANALYSIS AND RESULTS

Enterprise Context. The Tashkent Tractor Plant (AgroTech Klaster brand) provides a relevant industrial context for examining assembly-based production processes, multi-model bills of materials (BOMs), procurement operations, inventory management, and production order coordination. The proposed framework is intended for potential evaluation in this environment; however, its implementation and operational effectiveness have not yet been empirically verified.

Implementation Sequence. The proposed implementation process comprises several interconnected stages: assessment of existing information systems and operational processes; standardization of master data and bills of materials (BOMs); synchronization of Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES); implementation of dynamic safety stock (SS) and reorder point (ROP) calculations; integration of AI-assisted demand forecasting; and comparative economic evaluation under managerial supervision.

Comparison of Static and Dynamic Inventory Management Policies. Static inventory management policies rely on predetermined replenishment thresholds, whereas dynamic policies periodically adjust these thresholds based on updated demand forecasts, production requirements, and supplier-related information. The proposed dynamic approach may improve the responsiveness of inventory decisions to changing operational conditions. However, its potential economic benefits, including improvements in inventory efficiency and production continuity, require empirical validation using actual enterprise-level data (Figure 2).

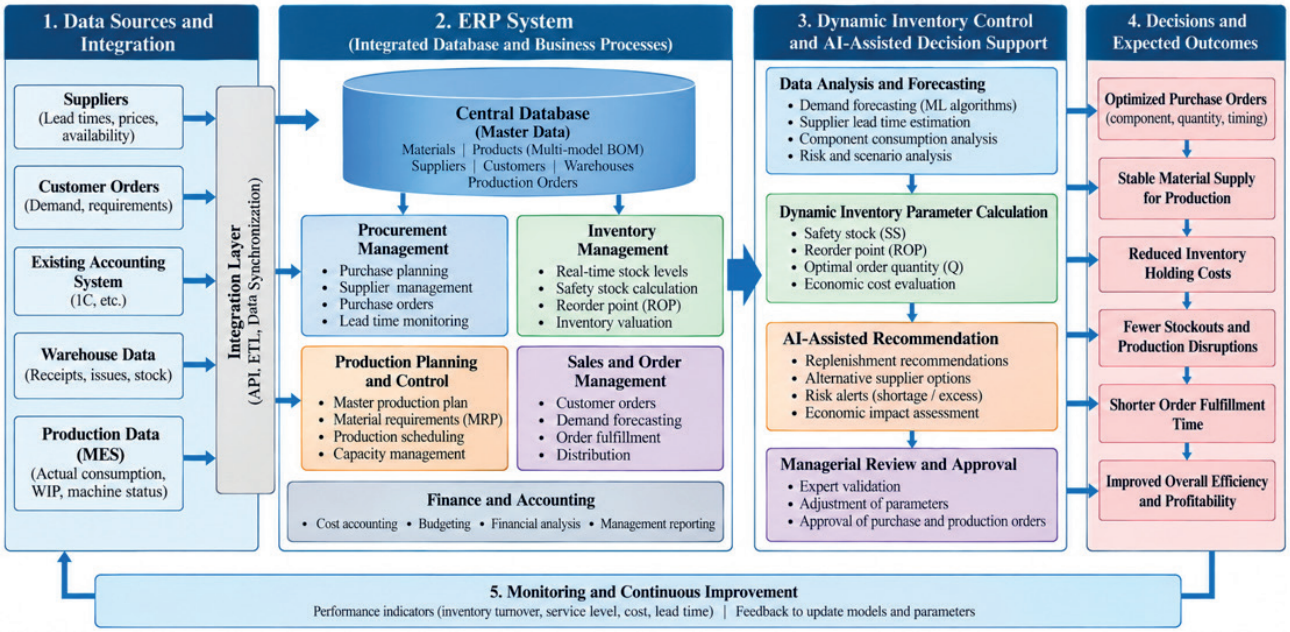


Figure 2. Proposed ERP-Based Integrated Management Framework for Dynamic Inventory Control and AI-Assisted Decision Support in Industrial Enterprises[3]

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The implementation of the proposed ERP-based integrated management framework requires a structured and sequential approach that ensures the coordination of technological, organizational, and economic components. Particular attention should be given to preserving existing system functionalities, standardizing operational data, synchronizing information flows, and establishing measurable criteria for evaluating integration outcomes.

In this regard, the study proposes a six-stage implementation framework encompassing system diagnostics, master data standardization, ERP/MES synchronization, dynamic inventory optimization, AI-assisted decision support, and comparative economic evaluation. Each stage specifies the principal integration activities, required inputs and control mechanisms, expected deliverables and acceptance criteria, and responsible organizational units. The proposed implementation stages are summarized in Table 2.

Table 2
Proposed ERP Integration Implementation Stages

Phase	Integration activities	Required inputs / controls	Deliverables / acceptance criteria	Responsible unit
1. Diagnose	Map accounting, procurement, warehouse and MES processes	Process maps, system interfaces, transaction samples	Integration gap analysis and approved scope	Process owners
2. Standardize	Unify material IDs, units, BOM versions and supplier data	Master-data dictionary, validation checks	Standardized BOM and reconciled master data	Engineering and data management
3. Synchronize	Integrate ERP, warehouse and MES transactions	API/ETL logs, timestamps, access controls	Reconciled transactions and exception reports	IT, warehouse and production
4. Optimize	Classify SKUs and calculate dynamic SS/ ROP	Demand history, lead times, service targets	Updated inventory parameters and backtesting results	Planning and procurement
5. Assist decisions	Generate AI forecasts, shortage alerts and recommendations	Validated models, supplier constraints	Cost-ranked recommendations for managerial approval	Analysts and management
6. Evaluate and scale	Compare baseline and pilot performance	Comparable production, demand and cost data	KPI assessment, net-benefit analysis and scaling decision	Finance and management

Note: SS — Safety Stock; ROP — Reorder Point; BOM — Bill of Materials; MES — Manufacturing Execution System; SKU — Stock Keeping Unit; API — Application Programming Interface; ETL — Extract, Transform, Load.

The effectiveness of the proposed ERP-based integrated management framework depends substantially on the adaptability of inventory control policies to changing production requirements, demand patterns, and supplier conditions. Conventional static inventory policies generally rely on predetermined demand estimates, fixed safety stock levels, and periodically reviewed replenishment thresholds. Although these approaches provide a structured basis for inventory planning, their responsiveness may be limited when operational conditions change frequently.

The proposed dynamic inventory policy seeks to improve this adaptability by incorporating rolling demand forecasts, bill of materials (BOM)-derived requirements, Manufacturing Execution System (MES) feedback, supplier-specific lead-time information, and continuously updated inventory parameters. The framework also integrates AI-assisted recommendations under human supervision to support economically informed replenishment decisions.

To identify the principal differences between these approaches, Table 3 presents a comparative assessment of conventional static and proposed dynamic inventory policies across seven operational and managerial dimensions, including their data dependencies and economic evaluation criteria (Table 3).

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Table 3
Static and dynamic inventory policies[4]

Dimension	Conventional static policy	Proposed dynamic policy	Update trigger / data dependency	Economic / validation implication
Demand signal	Fixed historic average or periodic plan	Rolling forecasts plus BOM-derived demand	Orders, planned output, MES actual consumption	Compare WAPE/MAE and service level
Lead time	Single assumed supplier lead time	Supplier-specific distribution and exceptions	Receipt timestamps, supplier delay events	Stress-test lead-time volatility
Safety stock	Fixed buffer by item	Service-level and variance-sensitive SS	Demand and lead-time uncertainty	Track holding vs shortage trade-off
Reorder point	Unchanged threshold during planning cycle	ROP recalculated after material change	Usable stock, receipts, reservations, lead time	Compare shortage events and capital tied up
BOM / MES	Limited or periodic synchronization	Revision-aware BOM and MES feedback	BOM revisions, production consumption, scrap	Track material discrepancy and interruption hours
Decision rights	Manual rule or periodic review	AI recommendation with human authorization	Forecast confidence, cost ranking, approval log	Audit acceptance rate and override reasons
Evaluation	Aggregate periodic reporting	Controlled baseline/ pilot or simulation comparison	Comparable time periods and SKU cohorts	Estimate net benefit without double counting

Illustrative calculation. Consider hypothetical demand of 20 units/day, expected lead time of 8 days, demand standard deviation of 5 units/day, lead-time standard deviation of 2 days and z=1.65. Then SS ≈ 71 units and ROP ≈ 231 units, rounded upward. These values are illustrative, not enterprise observations. The result highlights sensitivity to lead-time uncertainty.

5. Labor and time economics. Processing-time savings can be estimated as:

$$\Delta T = \sum_{j=1}^{n} \left(T_{j,0} - T_{j,1}\right) N_j \quad (6)$$

$$E_L = \Delta T \, C_L \quad (7)$$

where Nj is transaction count and CL relevant hourly labor cost. Released staff capacity is not automatically cash payroll savings. Annual net benefit is:

$$E_{\text{net}} = E_L + E_I + E_D - C_{\text{ERP}} - C_{\text{AI}} \quad (8)$$

where EI denotes inventory cost savings, ED avoided interruption costs, and CERP and CAI incremental integration and analytics costs. Benefits must be mutually exclusive.

Evaluation indicators. Inventory turnover (COGS / average inventory), shortage frequency, holding costs, material-related interruption hours, on-time order fulfillment, transaction processing time, forecast error and net economic effect should be compared before and after intervention or via controlled simulation. Changes in product mix, output volume, supplier performance and demand should be controlled where feasible (Table 4).

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Table 4
Empirical validation indicators[5]

KPI / unit	Operational definition	Required data fields	Comparison / statistical control	Expected direction (hypothesis)
Inventory turnover / times	COGS ÷ average inventory value	COGS, periodic inventory valuation	Matched SKU cohort; price and output mix	Increase, subject to service constraint
Stockout frequency / %	Shortage events ÷ demand events × 100	Demand events, shortage flags	Control demand variability and SKU criticality	Decrease
Material stoppage / h	Production hours lost specifically to component shortage	MES downtime code, production orders	Normalize by scheduled production hours	Decrease
On-time fulfillment / %	Due orders completed on time ÷ due orders × 100	Promised and actual completion dates	Control product mix and order volume	Increase
Transaction cycle / min	Mean end-to-end minutes per matched transaction type	Event timestamps, process identifier	Same transaction type and complexity	Decrease
Forecast error / WAPE	Sum |actual−forecast| ÷ sum actual × 100	SKU-level actual demand and forecasts	Rolling-origin time-aware backtest	Decrease (not guaranteed)
Data reconciliation / %	Matched ERP–MES–warehouse transactions ÷ total eligible × 100	Transaction IDs, quantities, timestamps	Report exceptions and missing records	Increase
Net benefit / currency	Avoided eligible costs + valued time savings − incremental costs	Holding, ordering, shortage, downtime, IT and labor	Exclude overlapping benefits; sensitivity analysis	Positive only if empirically demonstrated

The principal methodological contribution of the study is the development of an integrated decision-making framework that links material requirements derived from bills of materials (BOMs), feedback from Manufacturing Execution Systems (MES), adaptive inventory replenishment thresholds, and human-reviewed AI-assisted recommendations with the economic costs associated with inventory management and production operations. The framework provides a conceptual basis for coordinating operational information and supporting economically informed managerial decisions. However, establishing its comparative effectiveness requires empirical validation using actual enterprise-level data.

CONCLUSION AND RECOMMENDATIONS

The proposed ERP-based integrated management framework conceptualizes digital integration as an organizational and economic mechanism rather than merely a software replacement initiative. It combines function-preserving data exchange, multi-model bills of materials (BOMs), feedback from Manufacturing Execution Systems (MES), dynamic inventory control parameters, and AI-assisted decision support subject to human authorization. The framework is intended for application in Uzbekistan's machinery manufacturing sector, particularly in enterprises that rely on imported components with variable supplier lead times.

The principal practical priorities include standardizing master data, integrating warehouse and production records, classifying components according to their criticality in maintaining production continuity, and conducting pilot tests of adaptive replenishment policies for selected inventory items before considering enterprise-wide implementation.

The study also identifies several methodological and implementation considerations that should be addressed in subsequent research. These include the need for empirical validation using transaction-level enterprise data, the refinement of simplifying assumptions underlying safety stock calculations, the improvement of data quality, the assessment of system integration costs, the monitoring of potential model drift, and the implementation of appropriate cybersecurity measures.

Future research should focus on conducting controlled comparisons between static and dynamic inventory management policies, quantifying incremental net economic benefits, and evaluating alternative forecasting

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and inventory replenishment models. Such investigations would provide a stronger empirical foundation for assessing the operational and economic effectiveness of the proposed framework and its potential for broader application in industrial enterprises.

Based on the proposed ERP-based integrated management framework, the following recommendations are offered:

1. Strengthen ERP Integration and Data Standardization. Industrial enterprises should prioritize the standardization of master data, the harmonization of multi-model bills of materials (BOMs), and the synchronization of ERP, warehouse management, and Manufacturing Execution Systems (MES). Particular attention should be given to maintaining data consistency, ensuring secure information exchange, and preserving the functionality of existing information systems. These measures can provide a reliable information foundation for coordinated production planning and inventory management.

2. Introduce Dynamic Inventory Control Through Pilot Implementation. Machinery manufacturing enterprises should consider gradually introducing dynamic safety stock and reorder point calculations, initially focusing on components with high shortage criticality and variable supplier lead times. Pilot implementation should be accompanied by systematic monitoring of inventory holding costs, material shortages, service levels, and production interruptions. Comparing pilot results with baseline performance would help determine the economic feasibility of extending dynamic inventory control across the enterprise.

3. Develop Human-Supervised AI-Assisted Decision Support. Enterprises should integrate AI-assisted demand forecasting, material shortage alerts, and cost-based procurement recommendations into existing managerial decision-making processes. Final operational decisions should remain subject to human authorization, supported by transparent approval procedures and regular model performance assessments. Particular attention should be given to forecasting accuracy, data quality, cybersecurity, and the evaluation of incremental net economic benefits to support accountable and economically justified management decisions.

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