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METHODOLOGICAL ASPECTS OF INTEGRATING ARTIFICIAL INTELLIGENCE AGENTS INTO CORPORATE ERP SYSTEMS

Summary. *The article presents a comprehensive analysis of methodological approaches to integrating artificial intelligence agents into corporate ERP systems, where environmental uncertainty, supply chain fragmentation, and accelerated operational cycles intensify the gap between transactional accounting and the need for managerial response. The study is conducted as a review and conceptual synthesis of peer-reviewed publications, extracting evidence on integration models, architectural configurations, governance mechanisms, and conditions of applicability, without quantitative aggregation due to methodological heterogeneity across sources. Particular attention is paid to the distinction between modular analytical add-ons and agent-based integration, which implies observable autonomy, action orchestration, and embedded accountability mechanisms. The analysis shows that prevailing practice keeps AI in a predominantly advisory role due to architectural isolation of ERP modules and the absence of formalized authority to alter process states. It is established that the greatest practical impact is achieved by shifting from "model attachment" to a unified, managed control loop that combines data quality, user acceptance, measurable outcomes, and explicit rules governing autonomy. The article demonstrates that requirements for explainability, security, and regulatory compatibility should be treated not as external constraints but as structural conditions for scalable agent-based integration in*

ERP systems. The findings are relevant to researchers and practitioners of digital transformation, enterprise system architects, IT and operations executives, and specialists in data governance and change management.

Key words: *ERP systems, artificial intelligence, intelligent agents, agent-based architecture, process orchestration, managed autonomy, data governance.*

Introduction. Integrating artificial intelligence into corporate ERP systems is becoming a crucial condition for sustainable enterprise management amidst uncertainty, supply chain fragmentation, and accelerating operational cycles. Classical ERPs are oriented toward transactional recording, regulated planning, and post-factum analysis, which limits their ability to operate effectively under fluctuating demand and the necessity for real-time decision-making. Consequently, traditional forms of automation scale poorly, reinforcing the role of manual approvals and reliance on individual experts. While AI possesses the potential to enhance the adaptability of ERP circuits, in practice, this capacity is only partially realized.

Existing approaches to AI implementation in ERP environments vary substantially regarding the depth of integration. Most frequently, AI is utilized as an analytical add-on for forecasting or risk assessment and is not included in the planning, execution, and process coordination loops. Such a modular and reactive approach retains AI in a recommendation role rather than that of a participant in the management cycle. A universal integration model has not been formed, as effectiveness depends on the ERP landscape architecture, data governance maturity, and requirements for explainability and regulatory compatibility. The research problem lies in the absence of a holistic and formalized methodological framework that views the integration of artificial intelligence into ERP systems as a managed agent-based system for decision-making and execution.

The aim of the study is to structure the methodological aspects of integrating AI agents into corporate ERP systems and determine the conditions

under which AI transitions from the role of an analytical tool to that of a subject within the management loop. To achieve this goal, the study intends to: analyze modern practices of integrating artificial intelligence into ERP systems; compare architectural and organizational models of AI agent implementation; identify conditions for the transition from analytical to agent-based integration; determine methodological requirements for the manageability, measurability, and sustainability of agent-based solutions.

The research hypothesis is that the effectiveness of AI integration into corporate ERP systems is determined not by the complexity of the models, but by the degree of their inclusion in a managed agent-based loop with formalized rules of autonomy, control, and measurable results. Such alignment reduces reliance on manual interventions and increases the sustainability of managerial decisions under conditions of constant change.

The scope of the study is limited to the analysis of methodological, architectural, and managerial aspects of integrating AI agents into corporate ERP systems. Primary attention is paid to questions of agency, implementation life cycle, governance, and result measurability. Economic, sectoral, and institutional factors are considered only insofar as they influence the design and practical realizability of agent-based AI circuits within the ERP landscape.

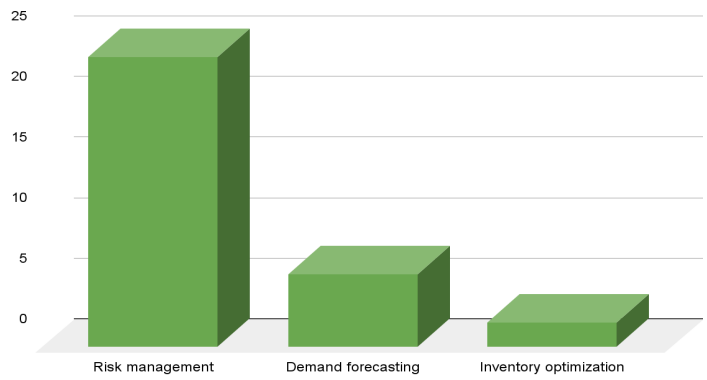
Materials and Methods. The methodological basis of the study was a corpus of ten scientific sources selected in accordance with the logic of a transparent and reproducible review. The analysis included review, conceptual, and empirical publications dedicated to the application of artificial intelligence in corporate ERP systems and adjacent management loops, including supply chain management, shared service centers, and IT service management. The inclusion criteria were thematic relevance to the task of integrating intelligent agents into ERP, an orientation toward methodological and architectural aspects, and the presence of conclusions applicable to corporate systems with elevated requirements for control, responsibility, and sustainability.

A number of sources record the current state of practice and its limitations. Studies by Al-Hourani and Weraikat [1] and Teixeira et al. [10] show that artificial intelligence is predominantly used for forecasting and risk analysis, remaining outside decision-making and execution loops, which is confirmed by the review of Jawad and Balázs [3]. The work of Jawad and Villányi Balázs János [4] shows that extending ERP with external unstructured data substantially improves the quality of managerial decisions and methodologically supports an agent-based approach. A model for the sustainable integration of artificial intelligence and ERP, combining readiness, acceptance, and result evaluation, is presented in the study by Islam et al. [2], while the strategic and service role of intelligent components is disclosed in the work of Mao et al. [6]. Architectural and organizational prerequisites for agent-based integration are examined in studies by Mannan et al. [5], Mishra and Tripathi [7], Patrício et al. [8], and Pinto et al. [9], with an emphasis on data management, responsibility distribution, and human-automation interaction.

The research method is based on conceptual-analytical synthesis and the comparison of selected works along agreed axes. The analysis covered the role of artificial intelligence in ERP as a tool for analytical support versus a participant in the management loop; architectural approaches to integration, from modular add-ons to an agent layer with process orchestration; implementation stages, including readiness, acceptance, result evaluation, and post-implementation sustainability; and manageability mechanisms, such as decision explainability, control, regulatory compliance, and security. An intelligent agent in the study is viewed as a subject of the ERP circuit capable of observing events, interpreting context, forming or initiating actions, and ensuring decision traceability with the possibility of human intervention. Limitations of the study are conditioned by the heterogeneity of the analyzed areas, differences in autonomy levels, and the limited number of empirical examples of full-fledged agent-based integration in corporate ERP systems.

Results. The obtained results show that the actual role of artificial intelligence in ERP-adjacent management tasks is more often limited to the analytical loop rather than autonomous process management. In observed practice, AI is predominantly used for risk assessment and forecast support, whereas functions of independent replanning and decision execution are represented significantly more weakly [1]. This is expressed in the fact that model outputs serve as inputs for subsequent human decisions or for regulated processing in ERP, rather than becoming grounds for automatic changes to plans and actions within processes.

The most consistent pattern appears in uncertainty management tasks. Risk-oriented scenarios are built around identifying deviations and warnings, after which the decision remains with the user or predefined system rules [10]. Demand forecasting is used as a means to increase calculation accuracy, but without translating the result into a mechanism for initiating changes in the "planning – procurement – production – distribution" chain [4]. Conversely, scenarios implying active influence on system state, including inventory optimization and dynamic adjustment of execution parameters, are encountered substantially less frequently and remain local in scale [3]. Figure 1 shows the distribution of functional AI/ML focuses, reflecting the current style of ERP integration.



Note: scale: 1 symbol = 1 study

Fig. 1. Functional role of AI/ML reflecting the current ERP integration style

Source: compiled by the author based on source: [1]

The diagram shows a clear dominance of analytical scenarios for AI integration in ERP. The largest share of research relates to risk management – 24 cases, indicating a priority on identifying threats and deviations without transitioning to managerial actions. Demand forecasting is represented substantially less frequently – 6 cases, reflecting the limited use of AI for active replanning. Inventory optimization is found in only 2 cases, which quantitatively captures the weak presence of AI in the operational ERP loop where autonomous decision-making and action execution are required.

The limitation of agency is connected primarily with integration architecture and rules of permissible autonomy, rather than with the computational capabilities of the models. The study by Islam et al. [2] emphasizes the necessity of measurable autonomy modes and action limitation mechanisms, without which AI remains in a recommendation role. A similar barrier is recorded by Pinto et al. [9], where requirements for accountability and decision traceability in responsible operational environments reinforce reliance on human intervention.

The obtained results show that including external unstructured signals in the demand forecasting loop qualitatively changes the operation of intelligent ERP components. The forecast begins to form not only based on internal system data but also taking into account the external environment context reflected in textual assessments and reviews. Such data expansion moves AI from an isolated analytical mode to a context-sensitive mode of interpreting changes not captured in transactional data.

Unlike the traditional use of forecasts as auxiliary calculations, the application of hybrid data forms a link between perception, interpretation, and potential managerial impact. This mode corresponds to the logic of an agent loop, in which the intelligent component correlates an external signal with a managed process and creates a basis for adjusting planning parameters [7]. Table 1 presents forecasting quality indicators when adding external textual features.

Table 1

Demand forecasting quality metrics under AI-driven ERP extension using sentiment-based pipeline

Demand forecasting quality metric	Value
Random Forest + sentiment: R^2	0.999939
Random Forest + sentiment: MSE	0.000125
Random Forest + sentiment: MAE	0.001073
Random Forest without sentiment: R^2	0.214
ARIMA baseline: R^2	0.842675
Dataset size (drug reviews)	>200,000

Source: compiled by the author based on source: [4]

The presented metrics illustrate the influence of expanding the input data space on forecasting quality, rather than the comparative effectiveness of specific algorithms.

It should be noted that the reported R^2 value, approaching unity, appears unusually high for demand forecasting tasks and may reflect dataset-specific conditions or methodological artifacts. Accordingly, these results should be interpreted with caution and require independent replication under diverse conditions prior to generalization.

They show that extending ERP circuits with external signals leads to a qualitatively different operating mode for the predictive model. They show that extending ERP circuits with external signals leads to a qualitatively different operating mode for the predictive model. A model using only internal data demonstrates limited ability to reflect real demand fluctuations, whereas adding contextual features eliminates the gap between formal system indicators and actual market behavior. At the same time, classical statistical approaches, despite an acceptable level of accuracy, retain dependence on past values and do not reflect changes in expectations and perception formed outside the ERP.

It is important to note that the observed improvement is connected not with the choice of a specific algorithm, but with the change in the principle of data integration. Including unstructured sources turns the forecast from a static calculation into an element of environment interpretation, which corresponds to the requirements of an agent-based ERP architecture oriented toward adaptation rather than just accounting [5]. This mode aligns with the service logic of management, in which the intelligent component becomes a connecting element between external signals and internal managerial parameters of the system.

Thus, the obtained results capture that the use of hybrid data creates prerequisites for transitioning from the analytical application of AI to an agent-based loop of perception and interpretation, in which the ERP gains access to external context and can be embedded in a broader cycle of managerial response.

Discussion. The obtained results allow viewing the integration of AI agents into ERP as a methodological task of forming a managed loop, rather than as a technical connection of models. Practice shows that the isolated implementation of intelligent components does not yield a sustainable effect without aligning organizational readiness, user acceptance, and methods for result evaluation. In this context, agency in ERP is formed through the consistency of infrastructural, organizational, and managerial factors, rather than through increasing the accuracy of individual algorithms.

A key condition for such alignment is the simultaneous presence of several interconnected components. These include system and organizational readiness, encompassing data quality, infrastructure reliability, and process maturity, which sets permissible boundaries for AI component autonomy [6], as well as the acceptance of intelligent decisions by users, based on perceived usefulness, transparency, and convenience of interaction with agent results [9]. The measurability of results, including the sustainability of effects after implementation and their correspondence to managerial goals, is also of

substantial significance. In the absence of alignment among these components, the agent loop in ERP remains formal.

Of separate importance is the observability of autonomy, which includes monitoring model performance characteristics, fixing the boundaries of independent actions, the reasons for decisions made, and conditions for human intervention [2]. These mechanisms are particularly important for ERP systems touching upon financially and regulatory sensitive processes, where security and embedded control act not as external constraints but as a structural element of agent-based integration. Figure 2 shows reported improvements in key indicators during AI integration with ERP, used to discuss success metrics and agent loop observability.

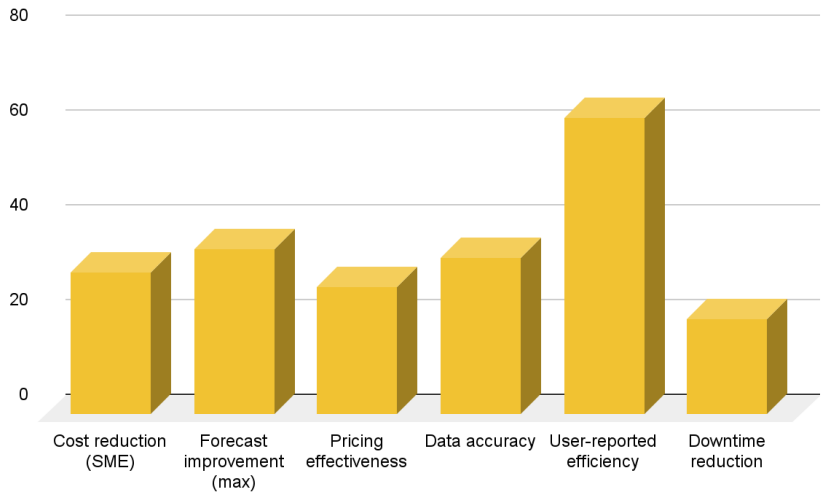


Fig. 2. Comparison of reported improvements in key metrics from AI–ERP

Source: compiled by the author based on source [2]

The diagram shows that the greatest improvement is associated with the subjectively perceived efficiency of user work – 62.5%, whereas operational optimization indicators are distributed more evenly. Improvement in forecasting reaches 35%, data accuracy increase – 33%, pricing efficiency growth – 27%, and the reduction of operational losses and downtime remains in the 20–30% range. Such a ratio of values indicates that the effect of integrating AI into ERP manifests simultaneously at the level of data, managerial decisions, and user

interaction, rather than being concentrated in a single functional dimension. Consequently, the discussed data emphasize that the methodology of integrating AI agents into ERP must rely on a coordinated life cycle, in which readiness, acceptance, measurability, and autonomy control form a single managed loop, rather than a set of disparate practices.

Modular integration of artificial intelligence into ERP forms the least invasive way of extending functionality. Intelligent components connect to separate modules and return results in the form of indicators or recommendations without affecting process management. This approach is considered safe and manageable; however, it is precisely this that solidifies the analytical role of AI and impedes the transition to agent-based interaction, wherein the intelligent component is capable of initiating actions.

The main limitation is connected with the architectural isolation of ERP modules. Historically, ERPs were built as systems of rigidly regulated circuits, where decision-making is divided between users and rules. Even with high accuracy, a module cannot influence neighboring processes or the system state as a whole, so AI ends up embedded in the computational but not the managerial layer. From an architectural perspective, intelligence is placed on the periphery, without access to the execution mechanism. Studies by Mannan et al. [5] and Patrício et al. [8] show that the transition to an agent-based approach requires allocating a separate orchestration layer, through which intelligent components interact with the ERP and become part of the managerial logic.

Thus, modular integration solidifies the gap between analysis and action, whereas the transition to agent-based architecture requires a redistribution of roles among the ERP core, intelligent components, and execution mechanisms, which fundamentally changes requirements for architecture, manageability, and responsibility within the corporate system. The obtained results confirm the proposed hypothesis that the key factor in AI effectiveness in ERP is the degree

of its inclusion in a managed agent-based loop, rather than the computational complexity of the models used.

Conclusion. Integrating AI agents into corporate ERPs must yield not just "smart analytics on the side" but a managed loop for decision-making and execution within processes. The key conclusion is that the result is determined not by the complexity of the models, but by how formalized the authority, control, and responsibility for autonomous actions are. Without this, AI remains an advisor, and ERP – a system for recording and regulation.

Observed practice shows a predominance of modular, reactive integration. Intelligent components more often identify deviations, form forecasts and recommendations, but do not become participants in the planning and execution cycle. This format is perceived as safe, yet it solidifies the gap between analysis and action and intensifies reliance on manual approvals. The transition to agent-based integration begins with architecture, not with connecting a model. An orchestration layer is needed that links events, context interpretation, and managerial action through controlled ERP interfaces. In this layer, autonomy boundaries, decision traceability, conditions for human intervention, and the distribution of responsibility between roles and loops must be defined.

A sustainable effect is achieved only with a coordinated implementation life cycle. Data and process readiness, user acceptance, and result measurability must be linked into a single management system where autonomy is observable and verifiable. In such an approach, security, regulatory compliance, and explainability act not as limiters but as constructive elements of agency, without which autonomous decisions in ERP cannot be scaled and consolidated in practice.

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