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Integrated system of performance indicators in the asset management of agricultural enterprises

Abstract. The paper proposes a unified system that links performance indicators (KPIs) with early-warning risk indicators (KRIs) to improve asset management under uncertainty in Ukrainian agribusiness.

Problem statement. Volatile input prices, logistics disruptions, climate risks and wartime shocks expose weaknesses of fragmented metrics and hinder transparent, comparable control of assets.

Unresolved issues. Standardization of KPI/KRI definitions for biological and fixed assets, links to risk appetite and capital allocation, data quality/digitalization gaps, and adaptation to national regulations remain insufficiently addressed.

Purpose of the article. To justify the concept, structure and practical guidelines for an integrated KPI-KRI system (IPIS) tailored to agricultural enterprises and harmonized with international practice.

Main material. The article outlines domains and metric passports, index-based tracking for comparability, threshold setting and escalation rules, data governance and reporting cadence, and use cases for capex/opex decisions, liquidity discipline, and stress-response. It adds a benchmarking grid versus EU practice to calibrate thresholds and reporting frequency. A lightweight dashboard is proposed for monthly management review, with quarterly external disclosure to enhance investor communication.

Conclusions. Implementing IPIS strengthens transparency, accelerates corrective actions, and supports efficient capital allocation; success depends on data quality, staff training, and phased integration into management routines. It also improves comparability across farms and seasons, facilitating lender and investor due diligence. Limitations include uneven digital maturity and potential measurement bias, suggesting phased pilots and future research on automated data capture.

Keywords: *agricultural enterprises; asset management; KPIs; KRIs; fixed assets; uncertainty; resilience.*

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Introduction. Agricultural enterprises combine long investment cycles of fixed assets with short and variable cycles of current assets, which heightens sensitivity to climatic fluctuations, logistical bottlenecks, market volatility, and institutional changes in access to infrastructure and resources. Traditional asset-performance assessment systems mostly record ex post results and detect nascent deviations too late, causing delayed managerial actions and losses that manifest as downtime, imbalanced turnover, and rising operational risk. The absence of a single control loop that links strategic objectives, performance indicators, and leading risk indicators into a disciplined: signal - threshold - action - escalation sequence leads to conflicts between unit-level targets and fragmented accountabilities. A conceptual model is needed that ensures traceability between goals and metrics, standardizes the interpretation of indicators, structures data governance, and embeds preventive control into the daily management practices of agricultural enterprises.

Since 2022, the war in Ukraine has profoundly transformed the operational and financial landscape of agricultural enterprises. Asset management systems now face unprecedented disruptions caused by destruction of production capacities, temporary occupation of territories, relocation of fixed assets, and volatility in energy supply and logistics. These factors have amplified uncertainty and exposed the inadequacy of reactive performance measurement models. The need for an integrated KPI–KRI framework has thus become not only a managerial tool but a resilience mechanism — one that enables rapid detection of deviations, prioritization of scarce resources, and coordination across dispersed or relocated assets. Studies of wartime agribusiness performance highlight the critical role of adaptive metrics and early-warning indicators in maintaining liquidity, operational continuity, and supply chain stability.

Literature review. In the Ukrainian scholarly tradition, the theoretical and methodological foundation for measuring the performance of agricultural enterprises and for constructing performance indicator systems was laid by V. H. Andriichuk [13], who substantiated approaches to assessing resource return and the asset structure at the enterprise level.

A comprehensive sequence of risk-management processes in agricultural enterprises (identification, analysis, assessment, treatment, and procedure documentation) was systematized by M. V. Rudenko [14], providing a methodological basis for integrating risk indicators into asset-management control loops.

Financial risks (price, interest rate, and foreign-exchange) and their mitigation through hedging with derivatives for agribusiness enterprises were examined in detail by Yu. O. Lupenko and V. V. Feshchenko [15]; these approaches are relevant for forming leading indicators and thresholds within the system's financial block.

Recent research underlines that the resilience of Ukrainian agribusiness during wartime depends on the integration of digital monitoring, scenario-based risk indicators, and traceable decision protocols. D.Omelianenko and M. Heyenko [9] offers a methodological toolkit for analysing the formation and efficient usage of assets within enterprises under uncertainty and risk. It addresses how assets are structured (fixed versus current), the pathways through which risk and uncertainty affect asset management, and proposes methods of assessment and optimisation.

D. Omelianenko [10] emphasizes the importance of asset management in the agricultural enterprise sector in Ukraine under conditions of economic instability and high risk. The work outlines methodological approaches to managing both current (circulating) and non-current assets (fixed, intangible) and links asset management effectiveness to financial results and resilience.

Ukrainian contributions provide a solid basis on efficiency, risks, and resilience of agricultural enterprises, yet they largely remain fragmented. There is a lack of an integrated framework that links outcome-oriented KPIs with leading risk indicators, uncertainty budgets, scenario-triggered actions, and data governance. The model proposed in this article closes this gap by shifting asset management from fragmented diagnostics to a preventive–corrective control loop.

Purpose, objectives and research methods. Purpose of the article - to theoretically substantiate and develop a conceptual framework for an integrated system of performance indicators and risk indicators as a mechanism for enhancing the effectiveness of asset management in agricultural enterprises under conditions of uncertainty. To achieve this goal, the study addresses the following interrelated tasks: to specify the methodological foundations for integrating performance measurement and risk management; to build a traceable hierarchy of goals, performance indicators, risk indicators, coordinated actions with a clear separation of leading and lagging metrics; to propose normative thresholds and uncertainty budgets as rules for transitions between management modes; to develop instruments in the form of an integration matrix and action cards templates for scenario-triggered responses; to define requirements for data architecture, roles, and review cadence to ensure controllability and reproducibility of processes; to outline enterprise-level implementation mechanisms that account for asset life cycles and logistics resilience; to justify quality criteria for the proposed artefact (usefulness, feasibility, explanatory power, transferability) and to indicate key limitations and avenues for further research.

The research is theoretical-conceptual within a constructive (design-science) approach: the objective is to form a managerial artefact in the form of an integrated system of performance and risk indicators. Systems analysis and structural–functional modeling are applied to build the hierarchy. Normative modeling is used: thresholds, uncertainty budgets, and scenario-triggered action cards are defined as policies with clear roles and escalation. The scenario method ensures linkage between early signals and standardized managerial responses with traffic-light zoning (green, yellow, red).

Content analysis of institutional sources helps extract stable risk-management procedures and incorporate logistics resilience and working-capital discipline into the core dimensions. Validation is carried out through logical consistency, procedural reproducibility, and compatibility with asset life cycles. The artefact's quality criteria are usefulness, feasibility, explanatory power, and transferability across enterprises. Limitations: absence of empirical calculations and statistical testing.

Research results. An integrated system of performance indicators and risk indicators is a continuous managerial control loop in which strategic asset objectives are translated into measurable outcome (lagging) performance indicators, while leading risk indicators convert early signals from the environment and internal processes into timely actions. The starting point of such integration is the requirement of traceability: for every goal there must be a clear goal - performance indicator pair and an attached set of leading indicators that warn of a change in the system's operating mode; this chain should be institutionalized in the form of a cause-and-effect map and response regulations [1]. The substantive logic here lies in synchronizing three axial dimensions of asset management: the productivity and reliability of fixed assets; the liquidity and turnover of current assets; and logistics resilience as an external constraint that modulates the ability to convert production efforts into realized value [5].

A crucial element is the separation of metrics into outcome (lagging) and leading ones, which is not merely terminological but assigns different roles in decision-making. Outcome indicators record the results of a season or reporting period, legitimizing or refuting chosen policies and initiatives, yet they cannot by themselves shorten the time lag between the emergence of a deviation and a corrective action. Leading indicators, by contrast, serve as operational sensors sensitive to micro-changes in equipment operating modes, inventory balance, counterparty behavior, and logistics infrastructure, enabling a shift to preventive management - that is, timely changes to schedules, routes, work sequencing, or rules for prioritizing supplies [3]. The danger of confusing these roles is that an organization either overfeeds itself with ex post reporting, losing speed, or takes impulsive actions based on raw signals without a validation framework; hence, discipline is needed for transitioning from leading indicators to outcome indicators through agreed decision gates [2].

The practical architecture of the integrated system in an agricultural enterprise provides for standardized passports for each performance indicator and risk indicator, specifying definitions, data sources, measurement frequency, zoning thresholds, and escalation routes. Such passports serve as carriers of organizational memory and as instruments for reducing information asymmetry among units: production, maintenance, logistics, procurement, and finance use a shared language of thresholds and interpretations, which lowers the likelihood of contradictory decisions in the presence of ambiguous signals [2]. Equally important are data quality and data governance: sources must be described, processes documented, cross-checks regular, and corrections transparently traceable. Such data discipline reduces false activations of leading indicators and, accordingly, the number of unnecessary interventions [4].

Table 1. Matrix for integrating goals, performance indicators, and risk indicators in asset management of an agricultural enterprise

Dimension	**Strategic goal**	**Key asset decisions**	**Examples of outcome performance indicators**	**Examples of leading risk indicators**	**Cadence & escalation**
Strategic	Season-year	Investment priorities; threshold policies; uncertainty budgets; stage-gate principles	Fleet readiness per season; loading-plan fulfillment; on-time dispatch rate; audit compliance	Infrastructure operating-mode changes; failure trends on critical components; trend in slow-moving inventory	Monthly review and seasonal retrospective; escalation to the management board [2]
Tactical	Month-quarter	Maintenance plan; equipment redistribution; buffer-stock adjustment; reserving warehouses/transport	Downtime share; inventory turnover; dispatch schedule adherence	Share of unplanned repairs; bottleneck signal; shortage of spare parts; payment deferrals	Weekly meetings with “action cards”; escalation to functional leadership [1]
Operational	Day-week	Work sequencing; route changes; minor repairs; temporary operating constraints	Daily/weekly plan fulfillment; average weekly dispatch time	Anomalies in condition parameters; queues at bottlenecks; deviations in fuel consumption	Daily stand-ups; rapid dispatcher-level escalation [3]

Source: prepared by the author.

The essence of the proposed logic is best illustrated at the intersection of fixed-asset management and logistics resilience. The goal of maintaining a high level of fleet readiness is reflected in the outcome KPIs availability ratio, share of downtime during the season, and loading-plan fulfillment, while the leading indicators are share of unplanned repairs in the current month, rate of deterioration in indirect condition parameters, and shortages of components or lubricants. The goal of minimizing logistics delays is specified by the outcome indicators on-time dispatch rate and average dispatch time, whereas the leading signals include notices from infrastructure operators, increases in waiting time at bottleneck sections, and reductions in available contracted transport. These dimensions are linked through scenario-triggered action cards: upon crossing into the yellow zone, warehouse and transport slots are reserved, routes are reallocated, and field-work schedules are temporarily adjusted, while in the red zone escalation goes to the executive level with authority to engage alternative channels and flexible budgets for expedited servicing [2].

Harmonizing thresholds for leading indicators requires a norm of permissible deviation in key parameters, which the article proposes to call uncertainty budgets. Their purpose is to align the system’s sensitivity with actual seasonality, execution windows, and logistics capabilities, so as not to generate over-reactivity while preserving response speed. In forming such budgets, the enterprise answers: what level of fluctuation in the share of unplanned repairs, slow-moving inventory, or waiting time at nodes does not yet undermine the ability to meet seasonal goals; what time interval between threshold crossing and action is operationally acceptable; where the yellow and red boundaries lie that separate management regimes [4]. When embedded in policy, uncertainty budgets create a common yardstick for different functions, reducing disputes over whether the system is over-sensitive or too slow.

Synchronizing the integrated system with asset life cycles ensures adaptability: for fixed assets, plan-fact reviews follow a seasonal cadence with deeper retrospectives, whereas for current assets and logistics they run on weekly or even daily micro-cycles, reflecting the high variability of the operating environment [5]. An important complement is a culture of operational sensitivity, whereby the team pays attention to weak signals and anomalies and has a legitimate, non-punitive channel for their escalation; such a culture enriches leading indicators with meaningful qualitative observations - especially useful under data incompleteness or noise [3]. Seasonal outcomes and incidents are fed back into system learning via a decision log, enabling subsequent cycles to recalibrate thresholds, refine indicator definitions, and revise scenario action cards in light of new information [2]. Practical guidance from sectoral agricultural risk-reduction programmes further specifies operational steps for integration, including early warning and shock preparedness [9]. In parallel, PARM frameworks demonstrate institutional mechanisms for aligning roles and responsibilities among stakeholders, which is valuable for scaling enterprise practices [10].

Table 2. Alignment of management levels, time horizons, and metric roles in the integrated system

Management level	**Decision horizon**	**Performance Indicators (Outcome)**	**Risk Indicators (Leading)**	**Coordinated Actions**
Financial efficiency	Increase asset productivity	Equipment productivity per season; share of green downtime; loading-plan fulfillment	Share of unplanned repairs per month; shortage of spare parts; deferred maintenance	Reallocate equipment; expedite maintenance; adjust the field-work schedule
Operational reliability	Reduce failures	Fleet availability ratio; mean time to failure (MTTF)	Rate of increase in vibration/temperature; lubricant shortages	Preventive maintenance; component replacement; adjustment of operating modes
Working-capital liquidity	Stabilize turnover	Inventory turnover; share of slow-moving inventory	Sharp buildup of critical items; payment deferrals	Clearance/redistribution; adjustment of the purchasing plan
Logistics resilience	Reduce logistics delays	Average dispatch time; on-time delivery rate	Signals of infrastructure constraints; vehicle-fleet shortages	Route reconfiguration; reserving warehouses/railcars
Environmental and Social compliance	Ensure adherence	Audit pass rate; absence of fines	Growth rate of fuel consumption; deviations in soil indicators	Maintenance; change tillage practices; supplier audits

Source: prepared by the author.

Horizontal integration of indicators across enterprise functions relieves the classic tension between production and financial goals, as well as between logistics and planning. For example, a decision to temporarily increase inventory buffers to reduce logistics risk must be aligned with the uncertainty budgets for turnover and with acceptable limits on disturbing the cash conversion cycle. If leading indicators suggest a looming bottleneck on a key route, the system enables an early, time-bounded increase of buffers specifically for critical items, with documented exit conditions for returning to normal - thereby lowering the likelihood of a prolonged inventory buildup [7]. Similarly, if the outcome indicator downtime share exceeded the target in the previous season, the team does not stop at stating the fact but analyzes the chain of leading indicators that preceded the deviation and revises the action card that failed to trigger with sufficient speed [2].

Discussion. In the context of regulatory and environmental requirements, the integrated system helps avoid formalism. Threshold indicators for emissions, fuel consumption, or soil tillage practices are embedded in the same control loop as production-logistics metrics, and their leading indicators (for example, the growth rate of fuel consumption in comparable operations) serve as early signals not only for compliance but also for optimizing operating modes. Thus, conformity with standards does not compete with efficiency; rather, it supports efficiency over a longer horizon, aligning with contemporary approaches to the sustainability of agricultural systems [11]. The conceptual economic tradition of distinguishing between risk and uncertainty suggests that, beyond statistical signatures, an organisation should work with regime shifts, when historical frequencies are of limited use and qualitative indicators and scenarios take the lead; hence the integrated system does not confine itself to retrospective diagnostics but emphasises sensitisation to weak signals and explicit rules of action [8]. These approaches correlate with the principles of resilience engineering, which stress foresight, preparedness for recovery, and learning from incidents [12].

It is also necessary to dwell on how the integrated system interacts with the capital-decision process. The stage-gate framework makes it possible to standardise the criteria for moving between phases - from investment initiation to asset commissioning - including through a set of KPIs that must be confirmed before proceeding, and KRIs that, conversely, block transition when risk thresholds are crossed. Such integration does not require complex optimisation models and works through rules, inspection schedules, and independent reviews, thereby reducing the likelihood of confirmation-bias traps in large projects [2]. As a result, capital discipline becomes an extension of operational discipline: leading indicators from the commissioning phase are carried over into the standard operating metric passports, ensuring seamless management.

In the context of wartime uncertainty, the integrated KPI–KRI system acquires a strategic function as an instrument of resilience engineering. For agricultural enterprises operating under shelling risks, power outages, or logistics disruptions, leading indicators become vital for anticipating regime shifts and coordinating decentralized decisions. The proposed framework enables early response to asset degradation or supply delays and supports dynamic reallocation of machinery and capital between safer regions. Its adaptability to fragmented operational environments makes it a viable foundation for post-war reconstruction planning, complementing national recovery strategies and donor-financed resilience programs.

Finally, building the review cadence requires not only rhythm but structural depth. Weekly meetings are dedicated to leading indicators, literal signals, and decisions for the next seven to fourteen days; monthly reviews focus on outcome indicators, trends, and policy adjustments; seasonal retrospectives focus on system learning, threshold revision, and updates to the action cards, as well as refining uncertainty budgets in line with new experience [5]. Importantly, each cadence level has its own decision set and escalation path so that the organisation does not confuse operational correction with policy-level rule revisions. This is precisely how flexibility over the short horizon is combined with rule stability over the longer horizon - essential for an agricultural enterprise with its combined cycles [1].

Conclusions. A conceptual framework for an integrated system of performance indicators and risk indicators has been developed and theoretically substantiated as a mechanism for improving the effectiveness of asset management in agricultural enterprises under uncertainty. The core idea is a shift from fragmented, primarily ex post measurement to a continuous managerial control loop in which goals are translated into outcome performance indicators, while leading risk indicators act as early sensors of regime shifts and trigger regulated actions. Such a loop not only shortens the time lag between the emergence of a deviation and the managerial response, but also increases decision alignment across production, logistics, procurement, and finance.

The proposed division of metrics into outcome and leading is not a terminological exercise; it assigns distinct managerial roles and reaction horizons. Outcome indicators legitimise and validate policies, enable assessment of goal attainment over the season or reporting period, and form the basis for system learning. Leading indicators, in turn, heighten organisational sensitivity to weak signals and micro-shifts in the condition of fixed assets, inventory turnover, and logistics infrastructure, shifting management into a preventive–corrective mode. Separating these roles eliminates typical distortions - where an organisation either overfeeds itself with retrospective reporting or makes impulsive decisions on raw signals without validation procedures.

The practical deployment of the framework is specified by two instruments. First, the integration matrix of goals, outcome performance indicators, leading risk indicators, thresholds, and action cards serves as a translation sheet from strategy to operational decisions, shortening the path from signal to action. Second, the alignment of management levels, time horizons, and metric roles establishes a clear review cadence: daily/weekly stand-ups for leading indicators, monthly reviews for outcome indicators, and seasonal retrospectives for system learning. Such a multi-level organisation prevents the mixing of operational corrections with policy-level rule revisions while preserving short-term flexibility.

The concept strengthens fixed-asset management through earlier detection of condition degradation, disciplined maintenance, and reduced downtime; for current assets it enhances control of accumulating imbalances, slow-moving stocks, and payment deferrals. Integrating logistics resilience into the same loop with production and financial metrics enables early responses to infrastructure bottlenecks and transport shortages by reserving capacity and reconfiguring routes. In the sphere of environmental and social compliance, threshold indicators and their leading signals help avoid formalism by turning compliance into an element of long-term efficiency.

An important managerial implication is the coupling of operational and capital discipline. Using a stage-gate logic for investment decisions - with clearly defined transition criteria for outcome indicators and blocking thresholds for leading indicators - reduces the risk of erroneous project escalation and ensures a seamless transition from commissioning to steady-state operations. Thus, capital discipline becomes an extension of, rather than an alternative to, operational discipline.

In sum, the integrated system of performance and risk indicators provides agricultural enterprises with managed sensitivity to uncertainty and improves asset-management effectiveness through four interrelated effects: shortening response time to deviations; increasing cross-functional decision coherence; reducing downtime and turnover losses; and institutionalising long-term compliance with sustainability requirements. The wartime application of the integrated KPI–KRI framework demonstrates its broader relevance as a resilience and reconstruction instrument, enabling agricultural enterprises to sustain performance management under extreme uncertainty and to transition faster toward post-crisis recovery.

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Інтегрована система показників ефективності в управлінні активами аграрних підприємств

Анотація. У статті запропоновано єдину систему, що поєднує показники результативності (KPI) з індикаторами ризиків раннього попередження (KRI) для підвищення ефективності управління активами в умовах невизначеності в українському агробізнесі.

Постановка проблеми. Волатильність цін на ресурси, збої логістики, кліматичні ризики та воєнні шоки виявляють слабкі місця фрагментованих метрик і перешкоджають прозорому, зіставному контролю активів.

Нерозв'язані аспекти. Недостатньо опрацьовано стандартизацію визначень KPI/KRI для біологічних і необоротних активів, зв'язок із ризик-апетитом і розподілом капіталу, прогалини в якості/цифровізації даних та адаптацію до національного регулювання.

Мета статті. Обґрунтувати концепцію, структуру та практичні настанови щодо інтегрованої системи KPI–KRI (IPIS), зорієнтованої на аграрні підприємства і гармонізованої з міжнародною практикою.

Основний матеріал. Стаття окреслює домени та «паспорти» показників, індексне відстеження для зіставності, встановлення порогів і правила ескалації, управління даними та періодичність звітності, а також приклади застосування для рішень щодо CAPEX/OPEX, дисципліни ліквідності та реагування на стреси. Додано матрицю бенчмаркінгу порівняно з практиками ЄС для калібрування порогів і частоти звітування. Запропоновано легку інформаційну панель для щомісячного управлінського огляду та щоквартального зовнішнього розкриття для посилення комунікації з інвесторами.

Висновки. Впровадження IPIS підвищує прозорість, прискорює коригувальні дії та підтримує ефективний розподіл капіталу; успіх залежить від якості даних, навчання персоналу та поетапної інтеграції в управлінські процедури. Система також покращує порівнюваність між господарствами та сезонами, полегшуючи процедури належної перевірки кредиторів і інвесторів (due diligence). Обмеженнями є нерівномірна цифрова зрілість і можливий зсув вимірювань, що зумовлює потребу в поетапних пілотах і подальших дослідженнях щодо автоматизованого збору даних.

Ключові слова: *аграрні підприємства; управління активами; ключові показники ефективності (KPI); ключові показники ризику (KRI); основні засоби; невизначеність; стійкість.*

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