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Article

Improving The Methodology for Assessing The Effectiveness of Digital Ecosystem Management in Higher Education

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Abstract: This article improves a methodology for assessing the effectiveness of digital ecosystem management in higher education. It distinguishes the scale of digitalization from management performance and proposes the composite OT-REBSI index. The index combines five blocks: process and service performance; data quality and interoperability; analytical management and decision impact; user and resource efficiency; and resilience, security, and institutional accountability. Target-based normalization, equal weighting, a critical-gap flag, data coverage, and institutional and student-weighted aggregation are substantiated. The methodology is intended as a diagnostic management tool for higher education institutions and the ministry.

Keywords: Higher Education, Digital Ecosystem, Digital Governance, Performance Assessment, OT-REBSI, Interoperability, Data Quality, Composite Index, Institutional Mechanism, Data-Driven Management

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1. Introduction

The new stage of digitalization in the higher education system is defined not by an increase in the number of information systems and platforms, but by the ability to accurately measure the management outcomes generated through them. The availability of digital services, the number of electronic transactions, or user coverage may indicate the scale of digitalization; however, these indicators do not, by themselves, demonstrate that data are generated with adequate quality, transformed into decisions, and ultimately produce measurable outcomes. Therefore, it is methodologically necessary to distinguish the level of digitalization from the effectiveness of digital ecosystem governance [1].

This need became even more pronounced from a regulatory perspective in 2026. Presidential Decree No. PF-58 of the Republic of Uzbekistan, dated April 10, 2026, establishes tasks to financially incentivize higher education institutions based on the results of the National Ranking starting from January 1, 2027; to assess the level of digitalization and graduate employment within the ranking; and to obtain the necessary data through the integration of government information systems. This situation requires digitalization to be measured not as an isolated technical indicator, but as an outcome-oriented criterion of institutional governance [2].

The comparability of the assessment methodology is also related to the diversity of the system in terms of its scale and composition. At the beginning of the 2025/2026 academic year, 215 higher education institutions were operating in the country, of which 97 were non-state higher education institutions, while the number of students reached

1.535 million. Under such conditions, an assessment based on the absolute number of users, services, or servers may automatically favor a large HEI because of its scale or, conversely, portray it as less efficient because of its higher workload. Therefore, indicators should be standardized in terms of users, transactions, process shares, or units of time [3].

The purpose of this article is to improve the methodology for assessing the effectiveness of higher education digital ecosystem governance in an outcome-oriented, verifiable, and comparable manner across different higher education institutions (HEIs). To this end, the OT-REBSI (Higher Education Digital Ecosystem Governance Effectiveness Integrated Index) is proposed. Its functional blocks, normalization and aggregation procedures, critical-gap condition, data coverage, and management-oriented interpretation are substantiated.

International approaches to assessing digital education ecosystems are increasingly focusing not merely on the availability of technology, but on its governance, user, and institutional outcomes. The OECD interprets the digital education ecosystem as an integrated system of technical, semantic, organizational, and legal interoperability, data reuse, governance, and trust mechanisms. In the absence of interoperability, linking and exchanging data becomes an error-prone process requiring considerable time and resources, whereas near-real-time data strengthen evidence-based decision-making [4].

Interoperability cannot be adequately represented solely by the number of APIs. Although information systems may be technically connected, management value is not created if the data are not semantically compatible or if users are required to re-enter the same information manually. Therefore, the proportion of transactions in which data are actually reused and duplicate data entry is eliminated represents a more direct measure of efficiency [5].

UNESCO emphasizes that the value of technology in education cannot be adequately assessed solely through the presence of implemented tools or access to technology. Its relevance, impact on equity, scalability, and sustainability should be considered jointly. From this perspective, technological capacity becomes a measure of governance effectiveness only when it produces a tangible impact on users, resource utilization, decision quality, and system sustainability [6].

The World Bank's GovTech Maturity Index (GTMI) assesses public-sector digitalization through dimensions covering core government systems and shared digital infrastructure, online public services, digital citizen engagement, as well as strategy, institutions, the legal environment, and digital skills. Although this model cannot be directly transferred to higher education, it provides a methodological basis for measuring complex digital governance through balanced functional blocks [7].

The United Nations E-Government Survey similarly evaluates digital development through a composite index that integrates services, infrastructure, and human capital. It emphasizes that systematically measuring the outcomes of digital initiatives can strengthen accountability in the use of public resources and enhance public trust [8].

The overall conclusion emerging from these international approaches is that assessment should focus not on isolated IT indicators, but on the integrated management outcomes generated by digital systems and their interaction with users, data, institutions, and decision-making processes.

Table 1. Key elements of assessing digital governance effectiveness in international approaches

Source	Assessment Focus	Key Methodological Element	Relevance to OT-REBSI
OECD Digital Education Outlook 2023	Digital education ecosystem	Technical, semantic, organizational, and legal interoperability; data reuse	Formation of the **D and Q blocks**

UNESCO GEM Report 2023	Value of technology in education	Relevance, equity, scalability, and sustainability	Incorporation of outcomes and sustainability into the **U and R blocks**
World Bank GTMI 2025	Digital maturity of the public sector	Assessment of systems, services, participation, and institutional factors across functional blocks	Logic of **balanced functional blocks**
UN E-Government Survey 2024	Digital government development	Composite assessment of services, infrastructure, and human capital	**Integrated index and systematic outcome monitoring**

Manba: OECD (2023), UNESCO (2023), World Bank (2025) va UNDESA (2024) materiallari asosida tizimlashtirilgan.

2. Materials and Method

The study employed systematic, comparative, and institutional analysis methods. In the first stage, international composite indices and methodological approaches related to digital education ecosystems were analyzed. In the second stage, the current information environment of Uzbekistan's higher education system, the objectives outlined in Presidential Decree No. PF-58, and the official indicators of the National Statistics Committee and the Ministry of Higher Education, Science and Innovation were systematized from the perspective of management outcomes. In the third stage, functional blocks, indicators, normalization procedures, weighting schemes, and interpretation rules were developed.

The effectiveness of digital ecosystem governance was interpreted not merely as the technical availability of an information system, but as its ability to ensure the lawful and timely generation of reliable data, reuse of data across systems, transformation of data into analytical signals, decision-making by authorized entities, and the achievement of measurable outcomes from such decisions. Accordingly, the object of assessment is not an individual platform, but the platform–data–user–governing entity–outcome chain.

The methodology is based on five principles. The outcome orientation principle directs indicators away from the mere existence of a system toward the outcomes of processes, services, or decisions. The verifiability principle requires the identification of the primary data source, formula, denominator, update frequency, and responsible entity. Comparability neutralizes differences in the size of higher education institutions through proportions, time-based measures, and transaction-based units. The limited compensation principle prevents a high overall score from concealing critical deficiencies in data quality or security. Management orientation transforms the index from a simple ranking instrument into a tool for diagnosis and the formulation of specific corrective actions.

The higher education institution (HEI) was selected as the primary unit of assessment. The results are interpreted at three levels: the individual status of an HEI, its comparative position relative to HEIs within the same category or group, and the overall system status at the ministry level. This three-level interpretation makes it possible to identify general trends and systemic gaps using a unified methodology while preserving the operational autonomy of individual HEIs.

3. Results and Discussion

Logical Architecture of the Assessment

In the proposed methodology, the calculation of the integrated index represents the final rather than the initial stage of the assessment process. First, the origins and characteristics of data from HEMIS, service logs, APIs and integration logs, user inquiries, execution records, and audit data are identified. This is followed by verification of the data source, reporting period, denominator, completeness, and audit trail. Only after these procedures are completed are normalization against the target thresholds, block-level scores, and the integrated OT-REBSI score calculated. The final interpretation identifies the

maturity level and critical gaps and feeds these findings into the HEI action plan, ministry-level monitoring, resource allocation, and subsequent reassessment [9].

This sequence reduces the risk of generating a precise index before the underlying data quality has been validated. At the same time, it ensures that the assessment result does not remain merely a statistical report but is directly linked to a subsequent management response. A key distinctive feature of the methodology is that the data source and denominator are treated as methodological elements of equal importance to the index value itself.

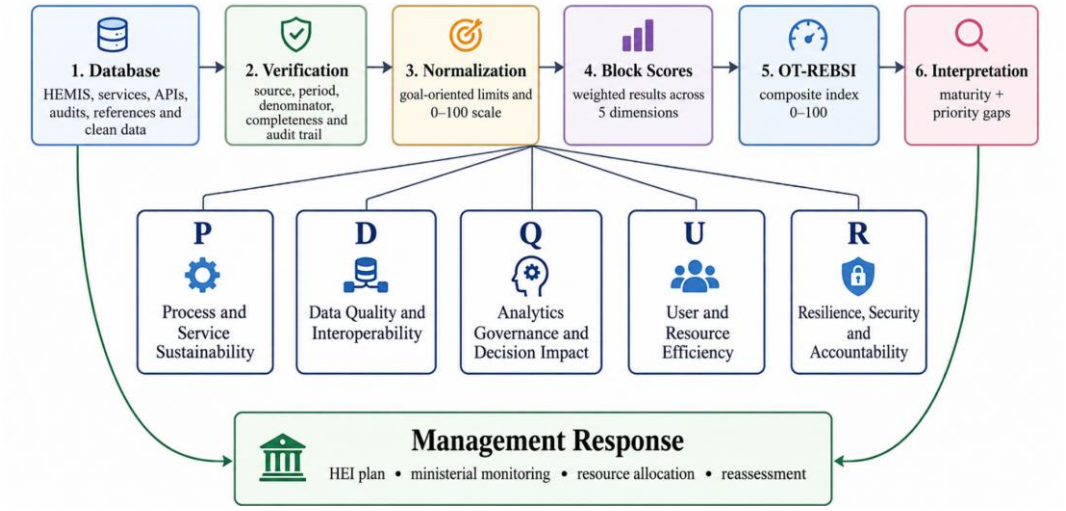

Figure 1. Logical architecture of the methodology for assessing the management efficiency of the higher education digital ecosystem.

Source: Author's development based on the approaches and research methodologies of the OECD, the World Bank GTMI, and the UN E-Government Survey.

Functional Blocks of OT-REBSI

OT-REBSI is calculated on a scale from 0 to 100 points and integrates five functional blocks: P – Process and Service Effectiveness; D – Data Quality and Interoperability; Q – Analytical Management and Decision Impact; U – User and Resource Efficiency; and R – Sustainability, Security, and Institutional Accountability. The blocks were selected not to repeatedly list problems within the digital ecosystem, but to transform them into measurable management outcomes [10].

The P block measures whether a process is completed electronically from end to end and within the specified timeframe. If an application is submitted electronically but requires paper-based approval at the final stage, the process is not considered fully digitized. Therefore, the main indicators are the proportion of processes completed electronically from end to end, the proportion of digital processes completed on time, and the reduction in repetitive manual operations.

The D block assesses the completeness of data, its timely updating, and the automatic reuse of data from primary sources [11]. The availability of an API does not necessarily indicate semantic compatibility of data or the elimination of repeated data entry. Therefore, the share of data reused in actual transactions is considered a priority criterion.

The Q block focuses not on the availability of dashboards or analytical modules, but on whether they are actually used in decision-making. Decisions with an evidence trail, response measures based on validated signals, and the re-evaluation of decision outcomes constitute the main components of this block. The U block assesses the successful completion of digital services, the intensity of user inquiries, and the administrative time spent per transaction [12].

The R block covers service continuity, critical incident recovery time, audit trails, and the clear identification of responsible entities. Measuring security solely by the number of incidents is inappropriate because the number of detected incidents may increase as monitoring improves. Therefore, the ability to detect, respond to, and recover from incidents is adopted as an outcome-oriented criterion [13].

Table 2. OT-REBSI blocks and key indicators

Block	Assessment Objective	Key Indicators	Data Source
P (0–20)	**Process and Service Effectiveness**	Full electronic completion; timely execution; reduction of repetitive manual operations	HEMIS, my.edu.uz, EduBilling, service logs, Ijro.gov.uz
D (0–20)	**Data Quality and Interoperability**	Completeness of mandatory fields; timely updating; automatic reuse of data from primary sources	HEMIS and registries, Data Hub/API logs, classifiers
Q (0–20)	**Analytical Management and Decision Impact**	Decisions with an evidence trail; action taken in response to valid signals; decisions whose outcomes are re-evaluated	Dashboards, HEMIS AI, decision cards, electronic document management system
U (0–20)	**User and Resource Efficiency**	Successful services; inquiries per 1,000 users; administrative time per transaction	Service logs, inquiry management system, call center, time monitoring
R (0–20)	**Sustainability, Security, and Accountability**	Uptime; critical incident recovery time; operations with an audit trail and an identified responsible entity	Technical monitoring, security logs, audit logs

Source: Author's own development, based on adapting the approaches of the OECD (2023), World Bank (2025), and UNDESA (2024) to the information environment and institutional requirements of Uzbekistan's higher education sector.

Normalization, weighting, and aggregation

Indicators are expressed in various units, such as proportions, time, transactions, and percentages. Combining them into a single index requires scaling them to a 0–100 range. Standard min-max normalization can lead to year-to-year instability in results due to changes in the composition of higher education institutions (HEIs) or fluctuations in extreme values. Therefore, it is proposed to normalize each indicator based on a predefined target value (T), a lower threshold (L) for positive indicators, or an upper threshold (U) for indicators where a decrease is considered positive.

$$s_i = 100 \times \text{clamp}[(x_i - L_i)/(T_i - L_i), 0, 1]$$

$$s_i = 100 \times \text{clamp}[(U_i - x_i)/(U_i - T_i), 0, 1]$$

The first formula is applied to indicators for which an increase represents a positive outcome, whereas the second formula is applied to indicators for which a decrease represents a positive outcome. Here x_i - denotes the actual value, T_i - represents the target value, and L_i va U_i - denote the lower and upper unacceptable thresholds, respectively. The target value is primarily linked to a regulatory requirement or service standard, followed by a service-level agreement (SLA), an approved ministry or HEI target, or, where such targets are unavailable, a baseline period and a planned improvement. Thus, the thresholds are not subjective but are justified by formal governance objectives.

In composite indicators, the choice of normalization, weighting, aggregation, and treatment of missing data can significantly affect the final results. Therefore, the formula should be transparent, reproducible, and accompanied by separately documented methodological decisions. In the baseline version of OT-REBSI, each of the five blocks is

assigned an equal weight of 0.20, while the three indicators within each block are also weighted equally [14].

Equal weighting represents a transparent and defensible solution at the initial stage. Once sufficient panel data have been accumulated, entropy weighting, factor analysis, or other objective weighting methods may be applied as sensitivity analyses. However, the results obtained from such methods should be reported separately from the baseline index. Statistical audits conducted by the Joint Research Centre demonstrate the importance of testing alternative weighting and aggregation scenarios when assessing the robustness of composite indices.

Table 3. Calculation elements and formulas of the ot-rebsi

Calculation Element	Formula	Interpretation
Positive-direction indicator	$s_i=100\times clamp[(x_i-L_i)/(T_i-L_i),0,1]$	The score increases as the actual value approaches the target.
Negative-direction indicator	$s_i=100\times clamp[(U_i-x_i)/(U_i-T_i),0,1]$	The score increases as the time, response time, or recovery time decreases.
Block score	$B_k=(s_{k1}+s_{k2}+s_{k3})/3$	The equally weighted average of the three indicators in each block.
Composite index	OT-REBSI=0,20(P+D+Q+U+R)	The equally weighted result of the five functional blocks
Data coverage	$C_i=100\times m_i/M$	Ratio of indicators with available valid data to the total number of mandatory indicators
Institutional average	$I\_inst=(1/N)\times\Sigma I_i$	Equal weight for each higher education institution; the "average HEI" scenario.
Student-weighted score	$I\_user=\Sigma(n_i\times I_i)/\Sigma n_i$	The "average user" experience, accounting for the number of students
Scale disparity	G=I_user−I_inst	It shows how major higher education institutions are affecting the overall system's results.

Source: Authors' own elaboration.

Arithmetic aggregation makes the results relatively straightforward to interpret for both managers and users. However, a high value in the P or U block may conceal serious deficiencies in the D or R blocks. Therefore, if any of the five blocks scores below 40 points, a **critical institutional gap** should be reported separately alongside the overall index. This flag does not artificially reduce the composite score; rather, it complements the managerial interpretation of the result.

Imputing missing data using the mean value may artificially improve or worsen the results. Therefore, imputation is not recommended for the 15 mandatory indicators. When valid data are unavailable, the indicator should be recorded as "data not available," while the coverage coefficient CiC_i should be reported separately. For example, if 12 of the 15 indicators have been verified, the data coverage rate is 80%. Under conditions of low data coverage, it is more appropriate to restore data governance processes before forcibly incorporating the institution into the ranking.

Digital Governance Maturity and Governance Response

Presenting the composite index solely as a ranking reduces the managerial value of the methodology. For an HEI, the key question is not its position in the ranking, but rather **which governance condition it is currently in and what the next appropriate step should be**. Therefore, OT-REBSI divides the composite index into five diagnostic levels using equal 20-point intervals. These intervals do not represent statistically derived clusters;

rather, they constitute practical governance ranges that may subsequently be refined on the basis of empirical data.

Table 4. OT-REBSI Digital Ecosystem Maturity Levels and Governance Responses

Score	Level	Diagnostic Meaning	Priority Governance Response
0–19.9	I. Initial	Processes operate separately, while the data and decision-making chain is disconnected.	Stabilize mandatory data, core processes, and accountability mechanisms.
20–39.9	II. Fragmented Functional	Individual platforms are operational, but outcomes and integration are inconsistent.	Reduce repetitive processes and standardize data quality and interoperability.
40–59.9	III. Integrating	Core workflows are connected, and some decisions are supported by digital evidence.	Strengthen monitoring of decision trails, user outcomes, and resource efficiency.
60–79.9	IV. Data-Driven	Decisions systematically rely on analysis, feedback, and measured outcomes.	Expand forecasting, risk signals, and cross-HEI benchmarking.
80–100	V. Adaptive and Outcome-Oriented	Processes, data, decisions, and outcomes are managed within a closed feedback cycle.	Scale innovative modules and conduct periodic methodological audits

Source: Author's development based on dividing the 0–100 scale into equal 20-point management maturity ranges.

Multi-level interpretation and management application

Reducing the individual indices of higher education institutions (HEIs) to a single simple average at the ministry level is insufficient. The institutional average assigns equal weight to each HEI and reflects the status of an "average HEI." In contrast, the student-weighted average better reflects the experiences of the large number of users studying at large HEIs. The "G" gap between these two indicators demonstrates the impact of large HEIs on the overall system result.

If G is negative, it indicates that large HEIs—which serve many students—are performing below the level of the "average HEI," meaning a significant portion of users are experiencing weaker digital management practices. If G is positive, large HEIs are achieving relatively higher results. This gap is not intended for punitive measures but rather serves to justify targeted support and investment allocation [15].

Comparing HEIs that differ in ownership (state vs. non-state), location (capital vs. regional), size (large vs. small), and educational profile using identical raw indicators can lead to methodological errors. Therefore, the OT-REBSI is interpreted not only through the overall index but also within the context of relevant peer groups. The fact that Decree No. PF-58 envisages maintaining the national ranking based on category groups further underscores the need to pre-establish comparison groups.

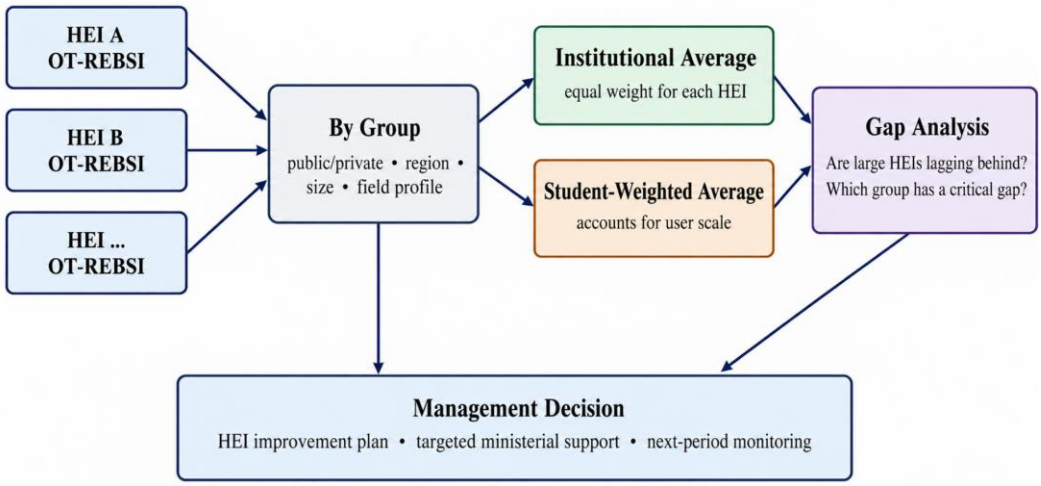

Figure 2. Scheme for the multi-level interpretation of OT-REBSI results and their transmission to management.

Source: Author's own work.

A high average value should not conceal substantial disparities among user groups. Therefore, rather than introducing a separate demographic coefficient into OT-REBSI, it is recommended that service indicators within the P and U blocks be disaggregated, within the scope of legally available data, by region, mode of education, public or private HEI status, and users with special needs. When significant disparities among groups are observed alongside a high composite score, this situation should be explicitly documented in the governance assessment.

Before OT-REBSI is adopted as an official instrument, a pilot assessment should be conducted for at least one complete academic year. The pilot should be used to identify indicator distributions and outliers, examine potential redundancy among indicators within the same block, and assess the sensitivity of results to different weighting and aggregation scenarios. The participation of public and private, capital-city and regional, as well as large and small HEIs would make it possible to test the methodological universality of the proposed framework.

Correlation analysis may serve as an additional instrument for assessing the validity of the methodology. HEIs with higher OT-REBSI scores should demonstrate improvements in the expected direction in the successful completion of digital services, the intensity of user inquiries, decision-making speed, and data quality. If the composite index is high while user-level outcomes do not improve, the composition of indicators or their respective weights should be reconsidered.

Practical Implementation of the Methodology

The indicators reported in the 2025 activity report of the Ministry of Higher Education, Science and Innovation demonstrate that an initial empirical data base for OT-REBSI is already available. The completion of 98.1% of the 2,511 tasks specified in presidential documents within the prescribed deadlines may serve as a signal of responsiveness within the P block. The receipt of 12,908 inquiries by the Ministry and their composition provide information relevant to user feedback within the U block. The elimination of risks amounting to UZS 28.7 billion in 385 cases through remote monitoring provides a practical basis for assessing the Q and R blocks. Meanwhile, the implementation of HEMIS AI services across HEIs indicates the availability of analytical tools within the Q block.

However, none of these figures, considered separately, proves the effectiveness of the digital ecosystem. Timely completion of tasks does not necessarily indicate the achievement of final outcomes; an increase in the number of identified risks does not automatically mean that security has improved; and the availability of HEMIS AI does not necessarily demonstrate that its analytical outputs have been incorporated into decision-

making. The purpose of the methodology is to connect existing indicators within a unified governance logic involving denominators, targets, decisions, and outcomes.

During the first stage of implementation, indicator passports and an inventory of data sources should be developed. Rather than increasing the burden of collecting new reports, priority should be given to existing data sources, including HEMIS, EduBilling, my.edu.uz, the appeals management system, Ijro.gov.uz, technical monitoring systems, and audit logs. During the second stage, a pilot assessment should be conducted with the participation of different types of HEIs to verify denominators, target thresholds, and the actual variation of indicators.

During the third stage, the formulas should be refined based on statistical sensitivity analysis, auditing, and user expert assessment. During the fourth stage, OT-REBSI should be integrated into the Ministry's dashboard as a diagnostic module. For each HEI, a one-page diagnostic profile should be generated, displaying the overall index, scores for the five functional blocks, critical-gap flags, and data coverage.

Decree No. PF-58 creates an institutional opportunity to link National Ranking results with financial incentives. Nevertheless, OT-REBSI should not replace the National Ranking. Instead, it can be applied as a complementary module that deepens the digitalization dimension of the ranking and provides internal diagnostics of digital governance effectiveness. At the initial stage, it would be advisable to use the index as a tool for developmental diagnostics and for directing technical support. Only after its auditability and stability have been demonstrated should it be linked to incentive mechanisms.

4. Conclusion

The findings of the study demonstrate the need to shift the assessment of the digital ecosystem in higher education from the question of “how much has been digitized?” to the more meaningful question of “what measurable governance outcomes has digitalization generated?” The number of platforms, services, or users may indicate the scale of digitalization; however, without linking these indicators to data quality, decision-making, and measurable outcomes, it is not possible to draw a comprehensive conclusion about governance effectiveness.

The proposed OT-REBSI methodology integrates digital processes, data integration, analytical decision-making, user and resource outcomes, sustainability, and accountability into a unified assessment cycle through five functional blocks. Target-oriented normalization improves the stability of year-to-year comparisons, while equal weighting of the blocks ensures the transparency of the baseline model. The critical gap flag prevents problems related to data quality or security from being concealed behind a high overall score.

The practical value of OT-REBSI is not limited to determining the score of an individual higher education institution (HEI). Institutional-level and student-weighted aggregation makes it possible to distinguish between the experience of the “average HEI” and that of the “average user.” Comparisons across groups also help prevent inappropriate comparisons of HEIs operating under different organizational and scale conditions based solely on raw indicators. The diagnostic profile supports the identification of root causes and targeted interventions by highlighting the weakest functional blocks.

The implementation of OT-REBSI should follow a sequential process consisting of the development of indicator passports and an inventory of data sources, a one-academic-year pilot assessment across different types of HEIs, statistical sensitivity analysis and methodological auditing, and subsequent integration of the methodology into the Ministry’s dashboard as a diagnostic module. At the initial stage, it would be advisable to use the index not as a mechanism for financial penalties, but as a tool for directing data governance, technical support, and institutional development measures.

Thus, OT-REBSI can theoretically serve as a measurement instrument for the chain of the digital ecosystem: "rules – actors – resources – digital processes – data integration – analysis – management decision – outcome." In practical terms, it enables HEIs to identify weak governance components and provides the Ministry with an evidence-based basis for determining system-wide standards, resource requirements, and institutional support needs.

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