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METHODOLOGY AND PRINCIPLES FOR THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN ADAPTIVE ECONOMIC MODELS OF HIGHER EDUCATION

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Abstract. The study develops a methodology and principles for applying artificial intelligence (AI) in the adaptive economic models of higher education institutions. It conducts a normative comparative analysis of the OECD AI Principles, the UNESCO Recommendation on the Ethics of AI and Uzbekistan's AI strategy, adapts the CRISP-DM process model to higher education economics, and classifies model families. Seven principles and their practical requirements are substantiated, and a six-stage methodological cycle and a model-selection map are proposed.

Keywords: artificial intelligence, adaptive economic model, methodology, explainability, CRISP-DM, data governance.

Annotatsiya. Tadqiqotning maqsadi oliy ta'lim muassasalarining adaptiv iqtisodiy modellarida sun'iy intellekt (SI) qo'llash metodologiyasi va prinsiplarini ishlab chiqishdan iborat. Metodologiya sifatida OECD SI tamoyillari, UNESCOning SI etikasi to'g'risidagi tavsiyanomasi va O'zbekistonning SI strategiyasini me'yoriy-qiyosiy tahlil qilish, CRISP-DM standart jarayon modelini oliy ta'lim iqtisodiyotiga moslashtirish va model sinflarini mezonlar asosida tasniflash qo'llanildi. Natijada SI ni qo'llashning yetti prinsipi va ularning OTM iqtisodiy modellari uchun amaliy talablari asoslandi, olti bosqichli metodologik sikl va model tanlash xaritasi taklif etildi. Xulosada yuqori xavfli moliyaviy qararlarda tushuntiriladigan modellarni ustuvor qo'llash zarurligi asoslandi.

Kalit so'zlar: sun'iy intellekt, adaptiv iqtisodiy model, metodologiya, tushuntiriluvchanlik, CRISP-DM, ma'lumotlar boshqaruvi, oliy ta'lim muassasasi.

Аннотация. Цель исследования - разработать методологию и принципы применения искусственного интеллекта (ИИ) в адаптивных экономических моделях вузов. Проведён нормативно-сравнительный анализ Принципов ОЭСР по ИИ, Рекомендации ЮНЕСКО об этике ИИ и стратегии ИИ Узбекистана, адаптирована модель CRISP-DM к экономике высшего образования, классифицированы классы моделей. Обоснованы семь принципов применения ИИ и их практические требования, предложены шестистапный методологический цикл и карта выбора моделей.

Ключевые слова: искусственный интеллект, адаптивная экономическая модель, методология, объяснимость, CRISP-DM, управление данными.

INTRODUCTION

The economic decisions of higher education institutions (HEIs)-including admission planning, tuition pricing, and investments in personnel and infrastructure-are made under conditions of numerous variables and uncertainty. Artificial intelligence (AI) makes it possible to make these decisions more data-driven and timely. However, the application of AI models to financial management requires methodological caution: a decision based on inaccurate data or an uninterpretable model may affect thousands of students and employees.

In Uzbekistan, this issue is gaining practical importance. The Strategy for the Development of Artificial Intelligence Technologies until 2030 [1] envisages the broad introduction of AI into public administration and economic sectors, while the Law "On Personal Data" [2] imposes strict requirements on the processing of student and employee data. Since state HEIs granted financial autonomy [3] have the right to make independent decisions regarding pricing and expenditures, the methodological requirements imposed on their analytical tools are also increasing.

The scientific problem lies in the fact that international principles of AI ethics are general in nature, while a methodological bridge that translates them into the practice of economic modeling in HEIs has not yet been sufficiently developed.

Research hypothesis: Transforming international AI principles into a system of specific methodological

requirements linked to each stage of HEI economic modeling, and relating model selection to the level of decision risk, can ensure the reliability of AI-based adaptive models and facilitate their acceptance by management.

LITERATURE REVIEW

The CRISP-DM model is widely used as a methodological standard for the process of extracting knowledge from data. C. Shearer described it as a six-stage iterative process consisting of business understanding, data understanding, data preparation, modeling, evaluation, and deployment [4]. In the field of education, G. Siemens and P. Long distinguished between learning analytics and academic analytics, showing that the latter serves institutional and financial decision-making [5]. B. Daniel analyzed the opportunities associated with the use of big data in higher education, along with issues of data quality and privacy [6].

Regarding model selection, L. Breiman contrasted the “data modeling” and “algorithmic modeling” cultures of statistical modeling [7]. C. Rudin argued that, in high-stakes decisions, interpretable models should be used from the outset rather than attempting to explain “black-box” models afterward [8]. In time-series forecasting, R. Hyndman and G. Athanasopoulos emphasized the need to compare models with simple baseline methods [9], while R. Sutton and A. Barto systematized reinforcement learning methods for sequential decision-making [10].

From a regulatory perspective, A. Jobin, M. Ienca, and E. Vayena analyzed 84 AI ethics guidelines and found that transparency, fairness, non-maleficence, accountability, and privacy were among the most frequently recurring principles [11]. The OECD AI Principles [12] and UNESCO’s Recommendation on the Ethics of Artificial Intelligence [13] have reinforced these principles at the international level. However, the reviewed sources address the application of these principles to the stages of HEI economic modeling only to a relatively limited extent.

RESEARCH METHODOLOGY

Three methods were applied in the study. First, through normative-comparative analysis, the OECD [12] and UNESCO [13] documents were compared with Uzbekistan’s AI strategy [1] and legislation on personal data [2], and general principles for HEI economic models were identified. Second, the CRISP-DM model [4] was adapted to the specific characteristics of higher education economics. Third, model classes were qualitatively classified according to the criteria of interpretability and flexibility [7; 8]. The classification is based not on quantitative measurement, but on general assessments commonly accepted in the literature.

ANALYSIS AND DISCUSSION OF RESULTS

Based on the synthesis of international and national documents, seven principles were identified, and each was translated into a specific requirement for HEI economic models (Table 1).

Table 1. Principles for the Application of AI in Adaptive Economic Models of HEIs¹

Principle	Source	Practical Requirement for the HEI Economic Model
Human oversight	OECD; UNESCO	The model provides recommendations only; final decisions regarding pricing, quotas, and staffing are made by the authorized body
Transparency and interpretability	OECD; UNESCO	For each forecast, the key factors and their effects are documented
Fairness and non-discrimination	OECD; UNESCO	Models related to grants, discounts, and payment deadlines are tested across social groups
Privacy	UNESCO; O’RQ-547	Student and employee data are anonymized and are not used for purposes other than those specified
Reliability and security	OECD; UNESCO	Model outputs are compared with a baseline model, and data are protected against leakage
Accountability	OECD; UNESCO	A responsible person and a review period are designated for each model
Proportionality	UNESCO; Resolution No. PQ-358	The complexity of the method is selected in accordance with the nature of the problem and the level of decision risk

The table shows that these principles are managerial rather than purely technical in nature. For example,

¹ Source: the author’s development based on [1; 2; 11; 12; 13].

the principle of fairness requires that models used for allocating grants or discounts should not systematically produce biased outcomes toward particular regions or social groups. The principle of proportionality, in turn, implies that the use of complex neural networks may not always be appropriate where a simple linear forecast is sufficient.

2. Methodological Cycle. The CRISP-DM model was adapted to the context of HEI economics and supplemented with a continuous monitoring block (Figure 1).

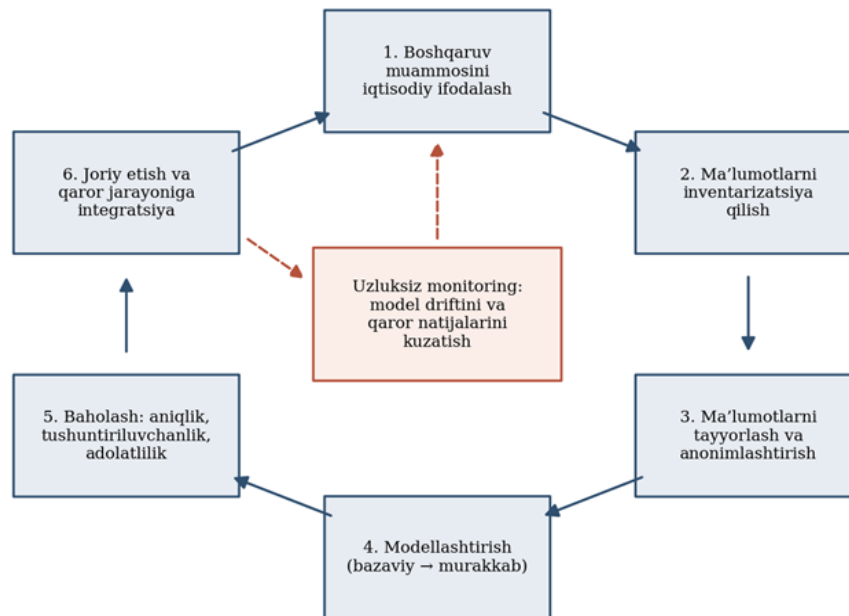


Figure 1. Six-Stage Methodological Cycle for the Application of AI in HEI Economic Models²

Unlike the original CRISP-DM model, the proposed cycle adds anonymization to the third stage and interpretability and fairness criteria to the fifth stage. The central monitoring block tracks model “drift,” that is, the decline in model accuracy resulting from changes in external conditions, and restarts the cycle when necessary. This applies the feedback principle of adaptive management to the life cycle of AI models. The content of each stage is presented in detail in Table 2.

Table 2. Content of the Stages of the Methodological Cycle³

Stage	Main Task	Methods and Tools	Quality Criterion
1. Problem formulation	Transform the management question into a measurable objective function	Indicator tree, agreement with stakeholders	Objectives and constraints are documented
2. Data inventory	Identify available data sources	Data catalog, metadata	Coverage and periodicity are assessed
3. Preparation	Cleaning, integration, and anonymization	Pseudonymization, imputation of missing values	Share of imputed values is recorded
4. Modeling	Develop baseline and advanced models	Regression, ARIMA, gradient boosting	Superiority over the baseline model is demonstrated
5. Evaluation	Assess accuracy, interpretability, and fairness	Cross-validation, MAPE, SHAP, group-level analysis	Meets the threshold for all three criteria

² Source: adapted by the author based on the CRISP-DM model [4].

³ Source: the author's development based on [4; 8; 9].

6. Deployment	Integrate the model into the decision-making process	Dashboard, recommendation and approval procedure	Responsible person and review period are defined
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To apply the principle of proportionality in practice, model classes were positioned along two dimensions-interpretability and flexibility (Figure 2).

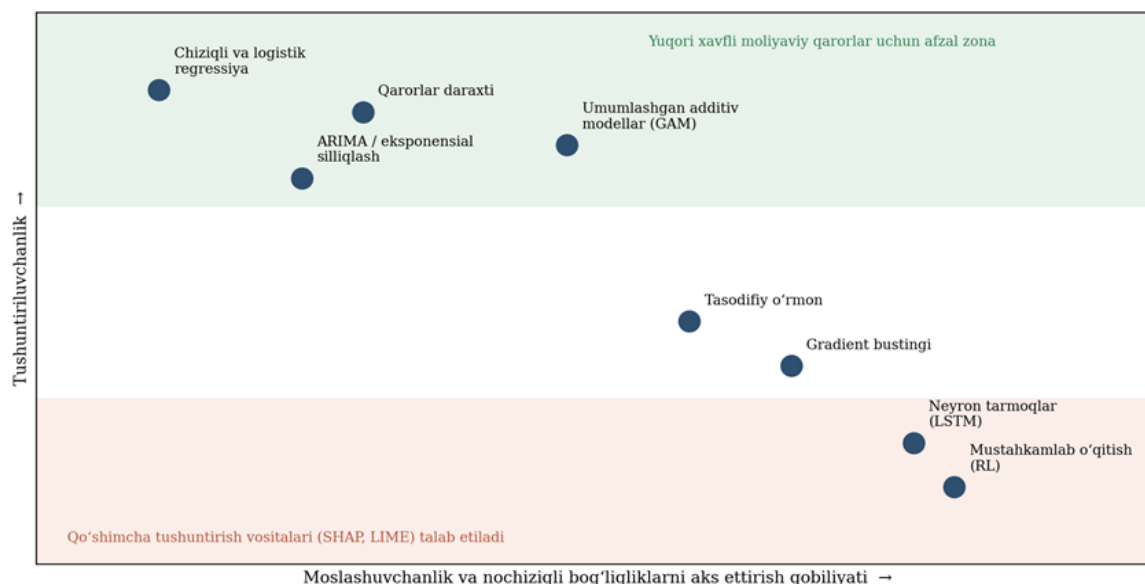


Figure 2. Model Class Selection Map (Schematic)⁴

The map links decision risk to the choice of model class. For high-risk financial decisions, such as setting tuition fees, allocating grants, or reducing staff, interpretable models located in the upper zone-regression models, decision trees, and generalized additive models-should be given priority. More complex models, such as gradient boosting and neural networks, may be applied to lower-risk operational tasks or used together with explanation tools. Reinforcement learning methods are promising for optimizing sequential operational decisions, such as classroom-space allocation or energy consumption; however, in financial policy decisions, their use is more appropriate primarily as a simulation tool. The results support the proposed hypothesis.

CONCLUSION AND RECOMMENDATIONS

As a result of the study, seven principles for the application of AI in adaptive economic models of HEIs and their practical requirements were substantiated, while a six-stage methodological cycle based on CRISP-DM and a model selection map were developed. The main conclusion is that, in the application of AI, technological complexity should not be treated as the primary criterion; instead, decision risk, data quality, and interpretability should serve as the key criteria.

Based on these findings, the following recommendations are proposed:

Adopt internal regulations governing the use of AI-based economic models in HEIs and establish the seven principles presented in Table 1 as mandatory requirements.

Maintain a "model passport" for each model, containing its purpose, data source, accuracy indicator, responsible person, and review period.

Give priority to interpretable models in high-risk financial decisions or require that the results of complex models be accompanied by mandatory explainability analysis.

Develop anonymization standards for processing student and employee data in accordance with the requirements of the Law "On Personal Data."

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⁴ Source: the author's development based on [7; 8; 10]; the positioning is based on qualitative assessments.

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