Management

UDC 330.46:004.415

DOI https://doi.org/10.5281/zenodo.19954378

Optimizing operational costs for ensuring the quality of digital products through predictive risk scoring

Iryna Kharchenko,

Master's Degree, CEO / Research Lead, Global Software Integrity & Digital Systems Initiative, West Sacramento, CA 95605, USA, https://orcid.org/0009-0005-3881-6392

Accepted: 08.04.2026 | Published: 30.04.2026

Abstract. *The article considers the problem of optimizing operating costs when ensuring the quality of digital products using predictive risk assessment in modern software development environments. The study's relevance lies in the need to balance high product quality and cost-effectiveness amid accelerating release cycles and increasing system complexity. The aim of the article is to examine methodological approaches to the adaptive distribution of testing resources based on predictive risk assessment to increase the cost-effectiveness of quality assurance processes. To address the tasks set, the following methods were used: analysis of the scientific literature to examine current developments in the field; generalization and systematization to present the research results.*

The study examined the economic nature of risk-based testing and its role in reducing inefficient resource allocation compared to traditional universal approaches. The applicability of predictive models, particularly the Quality Risk Score (QRS), as an integrated indicator that combines code complexity, defect

density, change variability, test coverage, and interaction instability to identify high-risk components was analyzed. It was found that using normalized and weighted indicators enables the formation of a consistent, scalable structure for assessing quality risks in dynamic CI/CD environments. The feasibility of implementing adaptive testing strategies that allow varying the intensity and scope of test activities based on calculated risk levels was substantiated. The study also analyzed the impact of this approach on key performance indicators, in particular the volume of test work, time consumption, and defect detection efficiency, demonstrating a significant reduction in overall costs while maintaining a high level of quality control. It has been found that adaptive redistribution of testing resources increases the efficiency ratio, reflecting a higher return on each unit of invested resources.

As a result, it was concluded that predictive risk assessment is an effective tool for achieving cost optimization while maintaining the reliability and competitiveness of digital products in rapidly changing technological environments.

Keywords: *risk-based testing, adaptive resource allocation, CI/CD environment, testing efficiency, risk assessment, software engineering, cost optimization.*

Оптимізація операційних витрат на забезпечення якості цифрових продуктів засобами прогностичного скорингу ризиків

Харченко Ірина Геннадіївна,
магістр, генеральний директор / керівник досліджень,
Global Software Integrity & Digital Systems Initiative,
Західний Сакраменто, Каліфорнія 95605, США,
https://orcid.org/0009-0005-3881-6392

Анотація. *У статті розглядається проблема оптимізації операційних витрат при забезпеченні якості цифрових продуктів за допомогою прогнозної*

оцінки ризиків у сучасних середовищах розробки програмного забезпечення. Актуальність дослідження пов'язана з необхідністю пошуку балансу між високою якістю продукту та економічною ефективністю в умовах прискорення циклів випуску й зростання складності систем. Метою статті є вивчення методологічних підходів до адаптивного розподілу ресурсів тестування на основі прогнозної оцінки ризиків з метою підвищення економічної ефективності процесів забезпечення якості. Для вирішення поставлених завдань було застосовано методи: аналізу наукової літератури – для дослідження поточних наукових напрацювань з тематики; узагальнення та систематизації – для представлення результатів досліджень.

Було розглянуто економічну сутність тестування, орієнтованого на ризики, та його роль у зменшенні неефективного розподілу ресурсів порівняно з традиційними універсальними підходами. Проаналізовано застосовність прогнозних моделей, зокрема Quality Risk Score (QRS), як інтегрованого показника, що поєднує складність коду, щільність дефектів, мінливість змін, покриття тестуванням та нестабільність взаємодії з метою виявлення компонентів високого ризику. Встановлено, що використання нормалізованих і зважених показників дає змогу сформувати послідовну та масштабовану структуру для оцінки ризиків якості в динамічних середовищах CI/CD. Обґрунтовано доцільність впровадження стратегій адаптивного тестування, які дозволяють варіювати інтенсивність та обсяг тестових заходів залежно від розрахованого рівня ризику. Проаналізовано вплив такого підходу на ключові показники ефективності, зокрема обсяг тестових робіт, витрати часу та ефективність виявлення дефектів, що засвідчило значне зниження загальних витрат за умови збереження високого рівня контролю якості. Встановлено, що адаптивний перерозподіл ресурсів тестування сприяє підвищенню коефіцієнта ефективності, що відображає вищу віддачу від кожної одиниці вкладених ресурсів.

У результаті зроблено висновок, що застосування прогнозної оцінки ризиків є ефективним інструментом для оптимізації витрат за умови збереження надійності та конкурентоспроможності цифрових продуктів у швидкозмінних технологічних середовищах.

Ключові слова: *ризик-орієнтоване тестування, адаптивний розподіл ресурсів, CI/CD середовище, ефективність тестування, оцінка ризиків, програмна інженерія, оптимізація витрат.*

Problem statement. The rapid proliferation of digital product ecosystems and the active adoption of continuous integration and continuous delivery (CI/CD) practices have made it difficult to maintain high-quality standards with limited time and resources, making the optimization of operational costs in quality assurance a critical and urgent issue. Traditional testing approaches, characterized by uniform and often excessive resource allocation, do not account for the heterogeneous risk profiles of software components, leading to inefficient cost structures, excessive test activities and insufficient attention to high-risk areas where defects can cause significant economic losses. In this context, the increasing complexity of digital systems, combined with growing market pressure for rapid product release, necessitates the development of more flexible and cost-effective methodologies that can dynamically align testing volumes with actual risk levels.

Predictive risk assessment is a promising solution to this problem, as it enables systematic identification, quantification, and prioritization of quality risks based on both historical and real-time data, thereby supporting more rational decision-making regarding resource allocation. The relevance of this study is enhanced by the need to improve the efficiency of quality assurance processes without compromising reliability, which allows companies to achieve the optimal balance between cost reduction and product performance in conditions of high competition and technological dynamics.

Analysis of recent research and publications. Various aspects of the researched issues are devoted to the scientific works of domestic scientists. In particular, the work of M. Heyenko and D. Omelianenko [1] substantiates methodological approaches to the analysis of the formation and effective use of assets under uncertainty, thereby providing a theoretical basis for assessing costs and risks in digital quality assurance systems. The study by V. Volikov and I. Panchenko [2] focuses on developing methodological tools for assessing innovation risks when integrating artificial intelligence systems, which is relevant to the development of approaches to predictive risk scoring for digital products. The work by O. Ptashchenko, O. Shersheniuk, and I. Kizilov [3] analyzed the impact of digital transformation on enterprises' innovative activity, confirming the need to adopt adaptive approaches to quality and cost management. The study by R. F. Atamaniuk, H. V. Yankovska, and I. M. Komarnytskyi [4] identified conceptual principles of project management that enhance operational efficiency, which is important for optimizing testing and quality control processes. The work by S. S. Semeniuk [5] is devoted to integrating digital technologies into the business processes of IT enterprises and emphasizes the importance of automation and digital tools in improving the efficiency of quality management. In the article by O. O. Artamonova and M. M. Luchkevych [6], the regularities of the formation of information systems for the optimization of cloud resources are investigated, which are directly related to the rationalization of costs in digital environments. The study by K. V. Cherviakov [7] presents models for flexible management of IT projects in the context of frequent releases, which serve as a basis for implementing adaptive approaches in CI/CD environments. The work by Y. Sierhieiev [8] analyzes methods for data preparation to detect code vulnerabilities within CI/CD processes, confirming the feasibility of using analytical approaches to assess quality risks. The study by V. O. Kulanov and A. Y. Perepelitsyn [9] proposes a method for creating projects using continuous integration and delivery technologies, emphasizing the

importance of automating development and testing processes to improve cost efficiency and the quality of digital products.

Highlighting previously unresolved parts of the general problem. Despite the significant number of scientific works devoted to risk assessment, digital transformation and business process optimization, modern research does not pay enough attention to the complex combination of economic and technical approaches to digital product quality management based on predictive risk scoring. In particular, there is no holistic methodology for adaptive testing resource allocation that would integrate formalized risk indicators with economic efficiency criteria. The quantitative assessment of the impact of risk-based testing on the optimization of operating costs in CI/CD environments remains insufficiently studied.

Formulation of the article objective (statement of the task). The purpose of the article is to examine methodological approaches to adaptive testing resource allocation based on predictive risk assessment to increase the economic efficiency of quality assurance processes.

In accordance with the goal, the following tasks were set and solved: to investigate the economic essence of risk-based testing of digital products; to analyze the methodological foundations of the formation and application of the predictive risk scoring (QRS) model in quality assurance systems; to substantiate approaches to adaptive distribution of testing resources depending on the level of risk; to assess the impact of the proposed approach on cost efficiency and effectiveness of quality control processes.

Presentation of the main research material. The key principles of predictive risk assessment in quality assurance systems are increasingly shaped by the need to balance high product quality with operational cost minimization in digital environments. In modern software development, particularly within the context of continuous integration and continuous delivery (CI/CD) approaches, the economic rationale of risk-oriented testing is to allocate limited testing resources to maximize

their marginal utility. Traditional unified testing approaches, which evenly distribute resources across all components, inherently lead to inefficiency due to excessive investment in low-risk areas and insufficient allocation to high-risk modules. From an economic perspective, this leads to suboptimal cost structures, increased opportunity costs, and reduced returns on quality assurance investments [9, p. 98]. Risk-based testing, on the other hand, introduces a prioritization mechanism that aligns testing intensity with the expected economic impact of potential defects, transforming quality assurance from a purely technical function into a cost optimization tool.

Within this concept, the Quality Risk Score (QRS) model serves as the primary analytical tool for quantifying and operationalizing software quality risks. The QRS model integrates many normalized factors that reflect both structural and dynamic characteristics of software systems, including code complexity, past defect probability, change variability, test coverage, and interaction instability. By combining these parameters into a comprehensive indicator, the model provides a quantitative, comparative risk assessment for all system components. This formalization allows modules to be classified into separate risk categories, which is the basis for differentiated testing strategies. Importantly, the use of normalized metrics ensures model consistency and scalability across development contexts, while the weighted QRS structure reflects the relative economic importance of each factor influencing the outcome. As shown in the basic methodological framework [10, p. 87], this approach allows for a systematic reduction in testing work without a proportional loss in defect detection, thereby increasing the overall efficiency of quality assurance processes.

Integrating predictive risk assessment models into decision-making processes in CI/CD environments is an important step towards automating and intellectualizing software quality management. Modern CI/CD pipelines are characterized by frequent code changes, rapid release cycles, and continuous

feedback loops, which require real-time, data-driven decision-making. In this context, predictive QRS-based models serve as built-in decision-support mechanisms that dynamically manage testing resource allocation, test case prioritization, and testing depth. Using both historical and real-time data, these models provide an adaptive response to changing system conditions, reducing the delay between risk detection and remediation [11, p. 581]. Also, their integration into automated workflows enables a transition from reactive to proactive quality assurance, where potential defects are identified and addressed before they become costly failures.

From an economic perspective, implementing predictive risk assessment within CI/CD not only improves operational efficiency but also contributes to strategic cost management by optimizing the balance between testing costs and quality outcomes. Practical data from simulated CI/CD scenarios indicate that such approaches can significantly reduce overall testing costs while maintaining a high level of defect-detection accuracy, thereby improving key performance indicators, such as efficiency ratios and return on investment in quality. Accordingly, the conceptual framework of predictive risk assessment can be considered a fundamental element in the evolution of quality assurance systems towards more economically sustainable and technologically advanced models. Methodological approaches to adaptive allocation of testing resources based on risk assessment formalize measurable indicators that reflect the structural and behavioral characteristics of software systems under constant change. Unlike generalized conceptual models, the methodological aspect focuses on operationalizing risk using quantitative variables and transforming them into metrics that are meaningful for decision-making. The formalization process involves selecting and normalizing key indicators that capture the probability and potential impact of quality deterioration.

Among the most important variables, it is worth highlighting: code complexity, which reflects the structural complexity of understanding and

maintaining the logic of the program; defectivity, which captures the historical perspective of defects in the component; variability of changes, which reflects the frequency and scale of code modifications over time; test coverage, which indicates the degree of functionality verification by automated tests; instability of interactions, which characterizes the module's susceptibility to errors that arise due to dependencies and integration points [12, p. 9729]. Each of these indicators is standardized on a single scale, allowing them to be combined into a comprehensive risk indicator that provides comparability across heterogeneous system components.

The methodological clarity of this approach lies not only in the definition of the corresponding indicators but also in their systematic interpretation within a classification system that directly determines testing strategies. Risk levels are usually divided into low, medium and high, each corresponding to a specific configuration of testing depth, volume and resource use intensity. This classification allows translating abstract risk values into concrete operational decisions, ensuring that testing efforts are proportional to the expected economic and functional consequences of potential defects. The correspondence between risk levels and testing strategies is summarized in Table 1, which shows the impact of changes in indicator values on prioritizing and distributing quality assurance activities.

Table 1

Risk level classification and corresponding testing strategies based on formalized indicators

Risk level	Indicator characteristics	Testing strategy	Resource intensity
Low	Low code complexity, minimal number of defects in the past, stable changes, high test coverage, low instability of interactions	Basic regression testing, preliminary tests	Reduced (selective allocation of resources)
Medium	Moderate complexity, single defects, periodic changes, partial coverage, moderate interaction risks	Standard regression testing with priority test cases	Moderate (balanced allocation)

ISSN: 2786-9431

Risk level	Indicator characteristics	Testing strategy	Resource intensity
High	High complexity, significant defect density, frequent changes, low coverage, high instability of interactions	Extended regression testing, exploratory testing, additional validation procedures	Maximum (full selection)

Source: author's development based on [11–14]

The practical implementation of this classification model requires the development of an adaptive mechanism for reallocating testing resources in response to dynamically changing risk profiles. Such a mechanism operates in CI/CD environments as a continuous feedback loop, where updated metric values lead to the real-time recalculation of risk scores and the subsequent adjustment of testing priorities. Testing resources are not just a technical adjustment, but a methodologically structured process that combines predictive analytics with management principles. Testing resources, including time, computing power, and human expertise, are allocated in a non-linear manner, focusing primarily on high-risk components and proportionally reducing attention to low-risk areas. This approach ensures that the marginal cost of testing matches the marginal risk reduction, thereby increasing the overall efficiency of the quality assurance process.

From an optimization perspective, the adaptive resource allocation mechanism serves as a lever to reduce unnecessary costs while maintaining, or even increasing, the efficiency of defect detection [15, p. 690]. By constantly reallocating testing resources, companies can avoid the economic inefficiencies associated with static testing models, such as over-execution of tests and under-testing of critical components. It should be noted that integrating formalized risk indicators into automated decision-making processes enables this methodology to be scaled to large, complex systems without a proportional increase in management costs. As a result, the methodological basis of adaptive resource allocation not only supports operational efficiency at the micro level of individual modules but also optimizes

quality assurance budgets at the macro level, thereby strengthening the strategic role of predictive risk assessment in modern digital product development.

Our empirical assessment of the effectiveness of cost optimization based on predictive risk assessment shows that transitioning from static to adaptive testing models delivers tangible economic and operational benefits in software development environments. Analysis of the impact of the adaptive testing model on operational costs shows a significant reduction in overall testing costs, primarily due to the differentiated allocation of resources based on dynamically calculated risk levels. In simulated CI/CD scenarios reflecting multi-cycle development processes, the adaptive approach reduced the overall testing workload by approximately one-third compared to baseline homogeneous testing strategies. This reduction is directly related to the elimination of redundant verification procedures in low-risk components and a focus on segments with the highest probability of defects. As a result, testing time was significantly reduced, resulting in lower labor costs and improved utilization of technical infrastructure. From an economic perspective, this transition reflects a move towards cost flexibility, in which quality assurance costs respond to actual system conditions rather than predetermined schedules.

At the same time, the analysis of defect-detection efficiency within the predictive approach shows that reducing testing volume does not lead to a proportional deterioration in result quality. Despite a reduction in allocated resources, the adaptive model maintains a high level of defect-detection efficiency, with only minor differences compared to traditional methods. Predictive prioritization of high-risk modules ensures a high probability of detecting critical defects, while less critical areas receive proportional attention at lower cost. This balance is evident in the accuracy of detecting high-risk components, where predictive scoring mechanisms demonstrate a strong ability to distinguish modules that require intensive testing. Although a small proportion of defects may remain undetected due to reduced testing in low-risk areas, the overall impact on system

ISSN: 2786-9431

reliability remains limited, since these defects usually correspond to lower levels of criticality. Therefore, the predictive approach provides a favorable balance between efficiency and effectiveness, aligning test results with economic rationality.

The overall effectiveness of predictive risk assessment can be further assessed by benchmarking key performance indicators that account for both cost and quality. Table 2 provides a summary assessment of the baseline and adaptive testing models, reflecting the relationships among test volume, defect detection, and overall effectiveness. The effectiveness factor, defined as the number of defects detected per unit of test volume, is the main indicator of efficiency improvement and indicates greater productivity of the adaptive approach.

Table 2

Comparative assessment of testing efficiency using the baseline model and the predictive risk-based model

Indicator	Baseline model	Predictive adaptive model
Total testing volume (%)	100	68
Time consumption (hours)	520	354
Defects detected (units)	312	305
Detection rate (%)	100	97,8
High risk identification accuracy (%)	–	89
Efficiency rate (defects per unit of effort)	0.60	0.86

Source: author's own development based on [16–19]

The data in table 2 clearly demonstrate that the adaptive model provides a significant increase in efficiency: the efficiency ratio improved by more than forty percent. This indicates that each unit of testing resources spent yields a greater result in the form of detected defects, thereby increasing the overall productivity of the quality assurance process. Importantly, the small decrease in the absolute number of detected defects is offset by a significant reduction in resource consumption,

resulting in a net positive economic effect. Increased accuracy in identifying high-risk modules further supports this result, ensuring proper attention to critical areas and thereby minimizing the likelihood of costly failures after release.

In a broader analytical context, the results obtained confirm the role of predictive risk assessment as an integrative mechanism that combines operational efficiency and strategic cost management [20, p. 1310]. By implementing data-driven decision-making into testing workflows, organizations can achieve a more balanced allocation of resources, reduce unnecessary costs, and maintain a high level of product quality. The results of the study also indicate that the effectiveness of such an approach extends beyond individual improvements in testing productivity to the overall optimization of software development processes, reinforcing the economic feasibility of predictive models in modern digital ecosystems.

Conclusions. As a result of the study, theoretical and methodological approaches to optimizing operational costs to ensure the quality of digital products were summarized, and the feasibility of transitioning from traditional static testing models to risk-based, adaptive approaches based on predictive risk scoring was demonstrated. The economic essence of risk-based testing as a cost rationalization tool that concentrates resources on the most critical elements of software systems, thereby reducing excess costs in low-risk areas, was substantiated. It is proven that the use of the QRS model, which integrates key quality parameters (code complexity, defectivity, change variability, test coverage and interaction instability), provides an objective basis for quantitative risk assessment and for making informed management decisions in CI/CD environments. It is established that an adaptive distribution of testing resources according to risk levels increases the efficiency of labor and time use, reduces overall testing costs and simultaneously maintains a high level of defect detection, confirming the economic feasibility of implementing the proposed approach.

Thus, the study's results indicate the significant potential of predictive risk scoring as a tool to improve the efficiency of digital product quality assurance processes. Prospects for further scientific research lie in the development and testing of models using machine learning methods to increase the accuracy of risk prediction and their integration into real production CI/CD environments.

References

1. Геєнко М., Омеляненко Д. Методичні підходи до аналізу формування та ефективного використання активів у рамках невизначеності та ризику. *Вісник Сумського національного аграрного університету. Серія: Економіка і менеджмент.* 2023. № 2 (94). С. 19–24. DOI: https://doi.org/10.32782/bsnau.2023.2.4.

2. Воліков В., Панченко І. Методичний підхід до оцінки інноваційних ризиків інтеграції систем ШІ (ADAS/CMS) у діяльність транспортних підприємств. *Вісник Хмельницького національного університету. Серія: Економічні науки.* 2025. № 348 (6). Р. 423–431. DOI: https://doi.org/10.31891/2307-5740-2025-348-6-61.

3. Пташенко О., Шершенюк О., Кізілов І. Вплив цифрової трансформації на інноваційну активність логістичних підприємств. *Журнал стратегічних економічних досліджень.* 2024. № 3. С. 140–149. DOI: https://doi.org/10.30857/2786-5398.2024.3.14.

4. Атаманюк Р. Ф., Янковська Г. В., Комарницький І. М. Концептуальні засади проєктного менеджменту в забезпеченні операційної результативності та маркетингової інтеграції. *Трансформаційна економіка.* 2025. № 4 (13). С. 9–13. DOI: https://doi.org/10.32782/2786-8141/2025-13-1.

5. Семенюк С. С. Інтеграція цифрових технологій у бізнес-процеси IT-підприємств; моделі, стратегії та перспективи. *Підприємництво та інновації.* 2025. № 36. С. 118–124. DOI: https://doi.org/10.32782/2415-3583/36.19.

6. Артамонов О. О., Лучкевич М. М. Чинники та закономірності формування інформаційних систем для оптимізації хмарних ресурсів. *Таврійський науковий вісник. Серія: Технічні науки.* 2025. № 3. С. 206–213. DOI: https://doi.org/10.32782/tnv-tech.2025.3.22.

7. Червяков К. В. Моделі гнучкого управління IT-проєктами в умовах високої частоти релізів. *Управління розвитком складних систем.* 2025. № 64. С. 153–160. DOI: https://doi.org/10.32347/2412-9933.2025.64.153-160.

8. Сєргєєв Є. Підготовка даних на основі графіків для виявлення вразливостей переповнення буфера в коді в рамках CI/CD-процесів. *Вісник Хмельницького національного університету. Серія: Технічні науки.* 2026. № 361 (1). С. 316–322. DOI: https://doi.org/10.31891/2307-5732-2026-361-45.

9. Куланов В. О., Перепелицин А. Є. Метод створення проектів на ПЛІС з використанням технології безперервної інтеграції та безперервної доставки. *Електронне моделювання.* 2025. № 47 (2). С. 92–107 DOI: http://doi.org/10.15407/emodel.47.02.092.

10. Козловський С. В., Чеботок В. В. Механізм ризик-орієнтованого управління в процесі цифрових перетворень. *Європейський науковий журнал Економічних та Фінансових інновацій.* 2026. № 1 (19). С. 83–99. DOI: http://doi.org/10.32750/2026-0108.

11. Okare P., Babawale D., Aduloju T., Ajayi O., Onunka O., Azah L. A CI/CD-integrated model for machine learning deployment in revenue risk prevention. *International Journal of Scientific Research in Science and Technology.* 2022. № 9 (1). P. 576–589. URL: https://sl1nk.com/pzih21x (date of application: 17.04.2026).

12. Li Z. Navigating digital transformation: A risk-based approach for Industry 4.0 innovation. *Journal of the Knowledge Economy.* 2025. № 16 (2). P. 9715–9751. DOI: https://doi.org/10.1007/s13132-024-02264-6.

13. Hilevska K. Predictors of economic efficiency of implementing human-centered models of children's integration into business-location environments. *Здобутки економіки: перспективи та інновації.* 2026. № 28. DOI: https://doi.org/10.5281/zenodo.19229499.

14. Paniotov D. Strategic Aspects of enhancing automotive service competitiveness through optimization of polishing technological processes. *Здобутки економіки: перспективи та інновації.* 2026. № 27. DOI: https://doi.org/10.5281/zenodo.18659827.

15. Patel H. K. Adaptive resource allocation using reinforcement learning for performance and cost optimization. *Journal of Computer Science and Technology Studies.* 2025. № 7 (9). P. 688–694. DOI: https://doi.org/10.32996/jcsts.2025.4.1.80.

16. Hunko I. Adaptive approaches to software testing with embedded artificial intelligence in dynamic environments. *International Journal of Current Science Research and Review.* 2025. Vol. 8, № 5. P. 2036–2051. DOI: https://doi.org/10.47191/ijcsrr/V8-i5-10.

17. Wiangkham A., Vongvit R. Integrating machine learning with FMEA for failure prioritization and process risk analysis in manufacturing. *Results in Engineering.* 2026. Vol. 9. 109128. DOI: https://doi.org/10.1016/j.rineng.2026.109128.

18. Chulayevska L. Safeguarding brand identity while scaling: strategic marketing for small and medium companies in the AI age. *Актуальні питання економічних наук.* 2026. № 21. DOI: https://doi.org/10.5281/zenodo.19094704.

19. Yatsemyrskyi L. Transformation of corporate client onboarding procedures through AI-enhanced intelligent recognition and integration systems. *Актуальні питання економічних наук.* 2026. № 20. URL: http://a-

economics.com.ua/index.php/home/article/view/1093 (date of application: 17.03.2026)

20. Dewi Y. Cost accounting system and risk governance: an integrated approach to risk management and cost efficiency. *Riwayat: Educational Journal of History and Humanities.* 2026. Vol. 9, № 1. P. 1306–1314. DOI: https://doi.org/10.66052/riwayat.v9i1.350