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Economic Efficiency of Automated Web Accessibility Testing for Reducing IT Enterprises' Operating Costs

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Abstract: *The relevance of this study is driven by the growing role of web-oriented services in the activities of IT enterprises, the tightening of regulatory requirements for web accessibility, and the need to optimize operating costs in an environment of continuous digital product development. Traditional approaches to web accessibility testing, which are largely based on manual testing, are characterized by high labor intensity, limited scalability, and substantial time expenditures, which adversely affect the economic efficiency of quality assurance processes. The purpose of this article is to provide a scientific justification for the economic feasibility of automating web accessibility testing as a tool for reducing operating costs and improving the efficiency of quality assurance processes for digital products of IT enterprises. The study employs systemic and analytical approaches to examine web accessibility automation in the context of production and economic processes, comparative analysis to contrast manual and automated testing methods, as well as methods of theoretical generalization and structural and logical analysis to formulate conceptual conclusions.*



In the results of the study, the impact of web accessibility testing on the structure of operating costs of IT enterprises was examined, and it was established that the automation of such testing increases the productivity of testing processes and shortens development iteration cycles. It was found that the integration of automated tools into continuous integration and deployment pipelines facilitates the early detection of typical violations of WCAG requirements and reduces costs associated with late-stage rework. It was demonstrated that automation contributes to the stabilization of the operating cost structure and increases its predictability. At the same time, challenges related to the limitations of automated methods, organizational barriers, and uncertainty in the quantitative assessment of the economic effect were identified. The conclusions summarize that the automation of web accessibility testing is an effective component of cost and quality management of digital products in IT enterprises, provided that automated and expert approaches are combined and systematically integrated into production processes. Prospects for further research are associated with the development of formalized models for assessing the economic efficiency of web accessibility automation, the improvement of methods for quantitative analysis of indirect economic effects, and the expansion of the functional capabilities of automated tools.

Keywords: digital products, software quality assurance, automated testing, operating costs, continuous integration and deployment, cost management, regulatory compliance, development productivity.

**Економічна ефективність автоматизації перевірки вебдоступності
для зниження операційних витрат ІТ-підприємств**

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Анотація: Актуальність дослідження зумовлена зростанням ролі веборієнтованих сервісів у діяльності ІТ-підприємств, посиленням регуляторних вимог до вебдоступності та необхідністю оптимізації операційних витрат у середовищі безперервної розробки цифрових продуктів. Традиційні підходи до перевірки вебдоступності, що базуються переважно на ручному тестуванні, характеризуються високою трудомісткістю, обмеженою масштабованістю та значними витратами часу, що негативно впливає на економічну ефективність процесів контролю якості.

Метою статті є наукове обґрунтування економічної доцільності автоматизації перевірки вебдоступності як інструменту скорочення операційних витрат і підвищення ефективності процесів контролю якості цифрових продуктів ІТ-підприємств.

У дослідженні застосовано системний та аналітичний підходи для вивчення автоматизації вебдоступності в контексті виробничих і економічних процесів, порівняльний аналіз для зіставлення ручних і автоматизованих методів перевірки, а також методи теоретичного узагальнення й структурно-логічного аналізу для формування концептуальних висновків.

У результатах дослідження вивчено вплив перевірки вебдоступності на структуру операційних витрат ІТ-підприємств та встановлено, що автоматизація таких перевірок підвищує продуктивність тестувальних процесів і скорочує тривалість ітерацій розроблення. Виявлено, що інтеграція автоматизованих інструментів у конвеєри безперервної інтеграції та розгортання сприяє ранньому виявленню типових порушень вимог WCAG та зменшенню витрат, пов'язаних із пізніми доопрацюваннями. Доведено, що автоматизація сприяє стабілізації структури операційних витрат і підвищує їхню передбачуваність. Водночас ідентифіковано проблеми, пов'язані з



обмеженістю автоматизованих методів, організаційними перешкодами та невизначеністю кількісної оцінки економічного ефекту.

У висновках узагальнено, що автоматизація перевірки вебдоступності є ефективним елементом управління витратами та якістю цифрових продуктів ІТ-підприємств за умови поєднання автоматизованих і експертних підходів та їх системної інтеграції у виробничі процеси.

Перспективи подальших досліджень пов'язані з розробленням формалізованих моделей оцінювання економічної ефективності автоматизації вебдоступності, удосконаленням методів кількісного аналізу непрямих економічних ефектів і розширенням функціональних можливостей автоматизованих інструментів.

Ключові слова: *цифрові продукти, контроль якості програмного забезпечення, автоматизоване тестування, операційні витрати, безперервна інтеграція та розгортання, управління витратами, регуляторна відповідність, продуктивність розроблення.*

Introduction. The digitalization of business processes and the rapid expansion of web-based services impose heightened demands on the quality, accessibility, and regulatory compliance of digital products developed by IT enterprises. Web accessibility, defined as the capacity of web resources to be fully perceived and utilized by all user categories, particularly individuals with disabilities, is evolving from a strictly socially oriented requirement into an economically significant determinant of competitiveness. In this context, adherence to web accessibility standards serves not only as a prerequisite for compliance with international and national regulations but also as a critical component of cost, risk, and reputational capital management for IT enterprises.

The practice of manual web accessibility testing, which is still widely used in the development and maintenance of digital products, is characterized by high labor



intensity, significant dependence on the qualifications of performers, and limited scalability. This leads to increased operating costs, longer software development lifecycles, and increased risks of untimely detection of critical accessibility violations. With the spread of agile software development methodologies and continuous integration and deployment, these limitations conflict with the need for rapid quality control and ensuring the economic efficiency of production processes.

Automating web accessibility testing is seen as a way to optimize costs and improve the effectiveness of digital product quality control, but its economic efficiency in IT companies remains insufficiently substantiated in scientific terms. On the one hand, the implementation of automated tools requires initial investment, process adaptation, and staff training; on the other hand, it potentially reduces testing costs, reduces the number of reworks, minimizes legal and reputational risks, and increases the stability of operations. The lack of a systematic analysis of the cost-benefit ratio of web accessibility automation complicates management decisions regarding its feasibility and scope of application.

Literature Review. A review of contemporary scholarly contributions indicates the emergence of several stable research directions that logically complement one another. First, researchers focus on issues of risk-oriented management, compliance, and the cost of maintaining complex and legacy digital systems. In particular, O. Gura substantiates that the integration of automated testing tools into continuous software delivery processes contributes to a reduction in operational costs and risks associated with the accumulation of technical debt. This perspective is methodologically consistent with the use of automated web accessibility (WA) verification tools as a preventive mechanism for reducing operating expenses (OpEx) [1].

M. Khanyi et al., analyzing the role of digital network solutions and application programming interfaces (API) in improving the operational efficiency of small and medium-sized enterprises, emphasize the importance of standardized



digital procedures for business process optimization. This, in turn, creates organizational prerequisites for the economically justified automation of quality control and accessibility of web-oriented products [2]. The significance of aligning technological and economic solutions, which makes it possible to interpret investments in automated web accessibility testing as a tool for enhancing the controllability of operating expenses in the long term, is examined by A. Ilyina [3].

Another area of scientific research is devoted to studying human capital, labor productivity, and the consumer value of digital services as sources of economic benefits from automation. Thus, A. Ilyina argues that investments in human capital in the context of the development of the information society must be accompanied by the introduction of digital tools capable of reducing unproductive labor costs and increasing the efficiency of intellectual resources, which directly correlates with the automation of standard web accessibility checks [4]. Researcher S. Subramanyam emphasizes that the application of business process automation using artificial intelligence (hereinafter referred to as AI) provides economic benefits by increasing operational efficiency and service quality, which is relevant to web accessibility as part of the user experience (UX) of digital products [5].

Researchers S. Kakolu and M. Faheem, analyzing the processes of digitization and automation of mobile applications, argue that improving the convenience and accessibility of digital services has a positive impact on user engagement and reduces support costs. These findings can be extrapolated to web platforms, where web accessibility contributes to the economic efficiency of digital products [6].

A significant part of the research forms the general economic context of automation as a factor in increasing operational stability and efficiency. In particular, S. Ivanov et al. consider automation as a tool for crisis management and improving the economic performance of companies, which allows automated web accessibility checks to be interpreted as a mechanism for reducing costs associated with regulatory, reputational, and market pressures [7].



Studying the economic efficiency of implementing enterprise resource planning (ERP) systems, A. Tambovcevs and T. Tambovceva argue that automation yields financial results only if it is integrated into management processes and cost control systems, which is of fundamental importance for evaluating automated web accessibility verification tools [8]. Analyzing the economics of robotization in the agricultural sector, J. Lowenberg-DeBoer and co-authors J. Lowenberg-DeBoer et al. demonstrate that automation reduces variable costs and compensates for labor shortages, which has direct analogies with the scaling of automated web accessibility checks in large IT projects [9].

A distinct body of research is associated with the integration of artificial intelligence, digital platforms, and process automation as a foundation for the long-term reduction of operating expenses. Thus, D. Sjödin et al. consider artificial intelligence as a driver of business model innovation and the development of firms' dynamic capabilities, which allows automated web accessibility testing to be interpreted as part of the strategic digital transformation of IT enterprises [10]. F.Tschang and E. Almirall analyze artificial intelligence as a complement to labor automation, emphasizing the feasibility of combining automated and expert-based solutions to achieve economic efficiency, which is relevant to the integration of automated and manual web accessibility assessments [11].

Investigating automation practices in industrial manufacturing, S. Reichenbach and B. Kromoser emphasize the importance of implementation maturity and process standardization for achieving economic benefits, which can be extrapolated to automated web accessibility testing tools in the IT environment [12]. Q. Tong et al. demonstrate that the integration of enterprise resource planning systems and warehouse management systems (WMS) in digital factories ensures a sustained reduction in operating expenses through end-to-end process automation. This finding confirms the feasibility of integrating automated web accessibility



testing into unified management frameworks for the development and operation of digital products [13].

Identification of previously unresolved parts of the general problem.

Despite a significant amount of research in the field of web accessibility, the economic aspects of web accessibility testing in the activities of IT companies remain insufficiently studied, in particular its impact on the formation of operating costs, the duration of development, and the effectiveness of testing processes. Unresolved issues include the quantitative assessment of the economic effect of automating web accessibility testing, the limitations of existing methodological approaches, and the impact of organizational barriers and uncertainty of the results of implementing automated tools on management decisions.

The proposed study aims to fill these gaps through a systematic analysis of the role of web accessibility in the structure of operating costs, an assessment of the economic factors and consequences of automation, and the formation of practical recommendations for its implementation. This allows for a deeper scientific understanding of the economic efficiency of automated web accessibility testing and increases the validity of management decisions in the activities of IT companies.

Formulation of the article's objectives (problem statement). The purpose of the article is to justify the economic efficiency of automating web accessibility testing as a means of reducing operating costs and improving the effectiveness of quality control processes for IT companies' digital products.

The objectives of the article are:

- 1) to analyze the economic role of web accessibility testing in the system of operating costs of IT companies and the prerequisites for automating the relevant processes;
- 2) to assess the impact of web accessibility testing automation on testing efficiency, development time, and the structure of IT companies' operating costs;



3) to substantiate practical recommendations for the implementation of automated web accessibility testing solutions in order to increase the economic efficiency of IT companies.

Presentation of the main research material. Web accessibility testing plays a significant role in shaping the operating costs of IT companies in today's digital production environment, as it is integrated into all the main stages of creating and maintaining web-oriented products. Web accessibility is considered to be the ability of web resources to be usable by a wide range of users, including people with disabilities, in accordance with the international recommendations of the Web Content Accessibility Guidelines (WCAG) [14]. Compliance with these requirements directly affects the cost structure of the enterprise due to the labor intensity of testing, the frequency of revisions, and the level of risks associated with the quality and regulatory compliance of digital products (Table 1).

Table 1

Impact of Web Accessibility Testing on the Structure of Operating Expenses of IT Enterprises

Cost Component	Nature of the Impact of Web Accessibility Testing	Economic Effect
Personnel costs	Involvement of developers and testers in the detection and remediation of accessibility violations	Increase or optimization of labor costs through standardization
Time costs	Additional testing iterations and repeated releases	Extension or reduction of the development cycle
Defect remediation costs	Elimination of errors at different stages of the product life cycle	Cost reduction provided that issues are detected at an early stage
Tool-related costs	Use of accessibility testing tools	Formation of controllable fixed costs



Risk-related costs	Consequences of noncompliance with accessibility standards	Reduction of legal and reputational losses
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Source: compiled by the author based on [1, p. 122; 2; 3, p. 76; 4, p. 285; 9, p. 286; 11, p. 650].

This structure reflects the typical practice of IT companies that develop corporate websites, electronic services, or software platforms for external customers. For example, in e-commerce projects, the lack of systematic web accessibility testing during the development phase often leads to massive interface rework after product launch, when problems with navigation, contrast, or assistive technology support are discovered [11, p. 650]. Such rework requires the re-engagement of development and testing teams and increases operating costs compared to a situation where accessibility requirements are taken into account from the initial iterations. For IT companies working with flexible development models, web accessibility testing is a regular operation associated with each functionality update [4, p. 285].

In the absence of automated approaches, this leads to an accumulation of time and resource costs, as the same typical violations are repeatedly checked manually. At the same time, early integration of accessibility checks into quality control processes reduces the cost of fixing defects, reduces the number of repeated iterations, and stabilizes operating costs. Thus, the role of web accessibility testing in shaping the operating costs of IT companies is not only to comply with social or regulatory requirements, but also to influence economic performance by changing the labor intensity of processes, cost structure, and level of operational risks in modern digital production.

The automation of web accessibility testing is influenced by a combination of economic factors and preconditions related to changes in the cost model of developing and maintaining web-oriented products. In an environment of scalable digital solutions and frequent functionality updates, manual approaches to accessibility control are becoming economically unviable due to the increase in unit testing costs and limited repeatability of results. Automated web accessibility testing



tools are seen as a means of redistributing costs from variable labor to relatively stable investments in tool and process infrastructure, creating the conditions for long-term resource savings (Table 2).

Table 2

Economic Factors in the Implementation of Automated Web Accessibility Testing Tools

Economic Factor	Manifestation in IT Enterprise Activities	Expected Economic Effect
Development scalability	Growth in the number of web projects and release frequency	Reduction of unit costs per product
Cost structure	Predominance of variable costs related to manual testing	Transition to controllable fixed costs
Cost of errors	High costs of defect remediation after release	Cost reduction through early detection
Time savings	Limited time frames for bringing products to market	Increased development cycle speed
Compliance risks	Contractual requirements and regulatory standards	Reduction of potential financial losses

Source: compiled by the author based on [3, p. 74; 4, p. 282; 5, p. 88; 7, p. 13; 8, p. 18; 9, p. 288].

The economic factors of web accessibility automation are implemented through a transition from sporadic, resource-intensive audits to regular automated checks integrated into the production processes of developing and maintaining web-oriented products. This transformation changes the economic logic of quality control: accessibility costs are no longer one-off and difficult to predict, but become a manageable part of the operating budget. According to analytical materials from the World Wide Web Consortium Web Accessibility Initiative (W3C WAI), automated testing tools are capable of detecting approximately 20-30% of violations of the Web Content Accessibility Guidelines (WCAG), but these violations are the



most common and typical errors that are repeated in a significant number of web components and account for a significant portion of manual testing costs [15].

A regulatory approach for United Kingdom to such integration can be found in the GOV.UK Service Manual, where automated web accessibility testing is defined as a mandatory element of the life cycle of public digital services. The document provides for automated checks during each code change, followed by manual refinement of only those aspects of accessibility that cannot be correctly assessed by algorithmic means. This reduces the number of defects that pass to the user testing or public release stage, and the time spent on fixing them is reduced several times compared to fixing similar problems after the service is launched [16].

In financial terms, this means a reduction in indirect costs associated with repeated development iterations and repeated approval procedures. Similar economic logic is embedded in the recommendations of the US federal resource Section508.gov, where the integration of accessibility checks into Continuous Integration and Continuous Deployment (CI/CD) processes is seen as a tool for reducing the total cost of ownership of digital products. According to the resource's analytical reviews, regular automated checks with each development iteration reduce the likelihood of critical accessibility violations accumulating, the elimination of which at later stages of the life cycle requires significantly greater financial and labor resources [17]. Thus, the automation of web accessibility testing serves as an economic safeguard that stabilizes operating costs and increases the predictability of management decisions in the field of web-oriented product quality.

Automation of web accessibility testing affects the activities of IT companies not at the level of feasibility or prerequisites for implementation, but at the level of measurable results of testing processes and the entire production system. This refers to changes in testing productivity, reduction of actual development time, and transformation of the internal structure of operating costs in project dynamics. Unlike the organizational and economic motives for automation, the effect of its



application is manifested in quantitative and process indicators that directly characterize the efficiency of software production (Table 3).

Table 3

Impact of Automated Web Accessibility Testing on the Performance of IT
Enterprises

Indicator	State without Automation	State with Automated Testing
Testing productivity	Limited by the throughput of manual checks	Increases due to parallel and repeatable test execution
Development duration	Increases because of late rework cycles	Decreases due to continuous monitoring
Post-release defect frequency	Higher, with the accumulation of accessibility-related errors	Lower due to early defect filtering
Cost structure	Uneven peak expenditures before releases	More even distribution throughout the cycle
Process manageability	Limited forecasting capability	Enhanced transparency and controllability

Source: compiled by the author based on [2; 7, p. 17; 8, p. 20; 10; 11, p. 652; 12; 13].

Automated tools make it possible to systematically identify accessibility violations at early stages of the product life cycle, thereby reducing the need for numerous manual iterations. For example, Slack integrated automated web accessibility testing using the Axe and Playwright tools into its software development workflows, which contributed to increased testing productivity and a reduction in the number of critical defects in final releases, as tests are executed automatically with each code change. This, in turn, reduces the workload on testing teams and enables the stabilization of quality assurance costs through the predictability and regularity of testing activities [18].

In this testing model, automated checks cover many fundamental accessibility criteria, such as the presence of alternative text for images, correct element semantics, and compliance with contrast requirements, which makes it possible to



significantly reduce the number of defects that would otherwise be passed to manual testing or addressed after release. As a result, the duration of development iterations decreases, and the structure of operating expenses shifts from an uneven model with peak workloads before release to a more evenly distributed model in which automated tools perform a substantial share of routine tasks. Such alignment between development speed, quality, and economic efficiency is essential for IT enterprises operating in an environment of frequent updates and high quality requirements for digital products.

Despite its proven effectiveness in identifying typical violations, the automation of web accessibility testing is accompanied by a number of scientific and practical problems that limit its full application and complicate the assessment of the economic results of its implementation. The main methodological problem is the limited ability of automated tools to formally assess context-dependent aspects of accessibility, in particular content comprehensibility, navigation logic, focus accuracy, and quality of interaction with assistive technologies, which requires subjective interpretation and expert involvement [9, p. 288].

As a result, automation does not eliminate the need for manual testing, but only changes the ratio between automated and expert procedures, which complicates the formation of universal models for evaluating effectiveness. Organizational barriers manifest themselves in the complexity of integrating automated web accessibility checks into existing development processes, especially in companies with fragmented team structures, a lack of uniform quality standards, and low maturity of development management processes. Insufficient awareness of accessibility requirements among developers and managers leads to the formal use of automated tools without further analysis of the results and systematic elimination of identified defects.

An additional challenge is resistance to change associated with the perception of web accessibility testing as an extra burden rather than as an element of quality



and cost management [8, p. 18]. A significant theoretical and practical issue remains the uncertainty of the economic outcomes of automation implementation, caused by the difficulty of directly measuring the effects of reducing the number of accessibility defects and their impact on financial performance. Economic benefits are often indirect and manifest as risk reduction, process stabilization, or avoidance of future costs, which complicates their formalization within traditional efficiency indicators. The lack of unified methodologies for calculating the return on investment in web accessibility automation limits opportunities for comparative analysis and informed managerial decision-making. Another limitation is the risk of excessive reliance on automated testing results, which may create the illusion of full compliance with accessibility requirements while critical but non-algorithmic violations persist.

The development and implementation of automated web accessibility testing solutions should focus on integrating these tools into the core production processes of IT enterprises, rather than using them as an isolated quality control stage. Implementing automated web accessibility checks in continuous integration and deployment pipelines is economically justified, as it ensures early detection of common violations and minimizes costs for late-stage refinements. This approach transforms accessibility costs from irregular and difficult-to-forecast expenses into a stable component of operational costs, manageable within standard budget planning.

To enhance economic efficiency, automated tools should be applied for large-scale and repetitive checks of basic accessibility criteria, combining them with selective expert audits for evaluating complex aspects of user interaction. A combined approach optimizes the use of human resources by focusing highly qualified specialists on analytical and design tasks rather than standard checks, which directly reduces the labor intensity of testing processes.



Furthermore, an important recommendation is establishing internal web accessibility standards and metrics linked to development efficiency and cost indicators, which enables evaluation of automation results from both technical and economic perspectives. Assigning responsibility for automated check results at the development team level reduces organizational barriers and prevents perfunctory use of tools without subsequent defect remediation.

Collectively, implementing these recommendations reduces operational costs by decreasing repetitive development iterations, stabilizing cost structure, and increasing predictability of production processes, thereby creating economic prerequisites for sustainable efficiency growth of IT enterprises in the digital environment.

Conclusions. This research established that web accessibility testing automation is an effective tool for reducing operational costs of IT enterprises and improving the efficiency of digital product development and testing processes. The study demonstrated that integrating automated checks into production processes ensures early detection of common WCAG requirement violations, reduces development iteration duration, and promotes formation of a more stable and predictable operational cost structure.

Concurrently, key challenges of web accessibility testing automation were identified, related to the limitations of algorithmic methods for evaluating context-dependent accessibility aspects, the complexity of integrating tools into existing organizational processes, and the uncertainty of economic outcomes from their implementation.

It has been shown that a significant part of the economic effect is indirect in nature and cannot be easily quantified within the framework of traditional performance indicators. The feasibility of using a combined approach that combines automated checks with selective expert audits and is implemented in continuous integration and deployment pipelines has been justified. This approach allows for



more efficient use of resources, improves the manageability of production processes, and reduces cost variability.

Prospects for further research are related to the development of formalized models for evaluating the economic efficiency of web accessibility automation, the improvement of methods for quantitative analysis of indirect effects, and the expansion of the capabilities of automated tools through the use of intelligent algorithms.

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