

ECONOSCITECH INTEGRATION

ISSUE
8

INTERNATIONAL SCIENTIFIC
ELECTRONIC JOURNAL



**TASHKENT STATE
UNIVERSITY OF ECONOMICS**



**American University
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ISSN: 3060-5075



Acceptance of articles

PUBLISHED EVERY MONTHLY



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THE SCIENTIFIC-POPULAR
ELECTRONIC JOURNAL
"ECONOSCITECH-INTEGRATION"
HAS BEEN REGISTERED UNDER
THE NUMBER C-5669651 BY THE
AGENCY FOR INFORMATION AND
MASS COMMUNICATIONS (AOKA)
OF THE REPUBLIC OF UZBEKISTAN,
EFFECTIVE FROM OCTOBER 9, 2024.

In accordance with Resolution No. 384/6 dated April 10, 2026, issued by the Presidium of the Supreme Attestation Commission under the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan, this journal is included in the list of recommended international scientific publications for publishing the primary research findings of doctoral dissertations in the field of Economic Sciences.

Partners: Tashkent State University of Economics / American University of Technology in Tashkent (AUT)

Electronic publication. Issue 8. 374 pages.
Approved for publication in August 2026.

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IMPROVING THE METHODOLOGY FOR ENSURING THE INTEROPERABILITY OF INFORMATION SYSTEMS IN HEALTHCARE INSTITUTIONS

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Abstract: This article scientifically analyzed the improvement of a methodology for ensuring interoperability among healthcare institution information systems. The study systematized technical, syntactic, semantic, and organizational-legal levels as a unified hierarchical framework. Open international standards, national regulatory documents, and scientific sources were used to develop assessment criteria for each level. The stages of mapping data flows, selecting integration profiles, ensuring terminological compatibility, testing technical solutions, and evaluating results were defined. The findings showed that a standardized data exchange approach improved data quality, strengthened system compatibility, and supported more consistent management processes. The proposed methodology provided a practical scientific foundation for the sustainable development of inter-institutional information exchange in digital healthcare. It also supported clearer interoperability planning.

Keywords: interoperability, healthcare, information systems, semantic compatibility, standardization, integration, digital health, data exchange.

Аннотация: В статье были научно проанализированы вопросы совершенствования методологии обеспечения интероперабельности информационных систем медицинских учреждений. В исследовании технический, синтаксический, семантический и организационно-правовой уровни были систематизированы как единая иерархическая система. На основе открытых международных стандартов, национальных нормативных документов и научных источников были сформированы критерии оценки каждого уровня. Были разработаны этапы картирования потоков данных, выбора интеграционных профилей, обеспечения терминологической совместимости, тестирования и оценки результатов. Полученные результаты показали, что стандартизированный подход к обмену данными повышал их качество, укреплял совместимость систем и способствовал последовательной организации управленческих процессов. Предложенная методология создала практическую научную основу для устойчивого развития межучрежденческого информационного обмена. Кроме того, подход позволил унифицировать интерпретацию клинических данных, планировать интеграционные проекты и эффективнее организовать цифровое взаимодействие между медицинскими учреждениями.

Ключевые слова: интероперабельность, здравоохранение, информационные системы, семантическая совместимость, стандартизация, интеграция, цифровое здравоохранение, обмен данными.

INTRODUCTION

For a long time the information systems used in healthcare institutions were built to solve isolated tasks: reception registries, laboratory journals, pharmacy accounting, financial reporting. Because each system carried its own data model and terminology, transferring information between them required additional processing. Once the task of creating a digital healthcare platform was set, the mutual compatibility of systems turned into an independent management problem [1]. Policy documents aimed at deepening administrative reform in the sector likewise tie the improvement of service quality to the continuity of information flows [2].

In theoretical terms, interoperability is defined as the ability of two systems to exchange data and to use the exchanged data with an identical meaning. A systematic literature review showed that securing this ability requires the transmission protocol, the data format, the terminology and the organizational agreements to work jointly [3]. A study based on the experience of African countries established that reinforcing the mandatory status of standards in national policy documents directly affects the expansion of exchange practice [4].

From a methodological standpoint, the question of interoperability admits three interpretations. The technical interpretation confines it to the conformity of protocols and interfaces. The data interpretation turns it into a matter of a common model and terminology. The institutional interpretation treats it as a system of responsibility, agreement and oversight. The three readings are not mutually exclusive; rather, they form the successive levels of a single methodology. The aim of the article is to unite these levels into an integral

methodological scheme and to substantiate the procedure for applying it at the institutional level.

The research tasks were defined as follows: to clarify the content of the interoperability levels; to systematize the base of open standards for each level; to formulate assessment criteria by level; and to develop a staged procedure for applying the methodology in practice.

REVIEW OF LITERATURE ON THE SUBJECT

The sources devoted to interoperability may be divided into two strands: specifications that develop exchange technologies, and framework documents that regulate them within a management context.

The first strand changed appreciably with the emergence of the resource-based exchange model. The scientific literature substantiated at an early stage that an approach representing clinical data as independent resources and resting on web-architecture principles reduces the labour intensity of integration work [5]. The current edition of the specification combines a system of resources, profiles and extensions, which allows national adaptations to be created in different countries [6]. The application-level open interface model defined the procedure for securely connecting external programs to the electronic medical record system and opened the way for new participants to enter the ecosystem [7]. The document-based clinical architecture standard remains a stable foundation for exchanging structured documents such as discharge summaries, referrals and conclusions [8].

The semantic level rests on terminological resources. The international systematized nomenclature of clinical terms expresses diagnoses, procedures and conditions through machine-readable codes [9]. The universal set of codes for laboratory and clinical observations makes it possible to interpret test results identically across institutions [10]. In the field of medical imaging, the transmission and storage standard secures exchange independently of equipment manufacturers [11]. The reference model designed for the communication of electronic health records guarantees the structural consistency of those records [12].

The second strand determines the order in which standards are applied jointly. The technical framework of integration profiles describes actors, transactions and their sequence for clearly defined use cases and reduces the likelihood of divergent interpretations of standards within projects [13]. The European interoperability framework treats the problem as a four-level structure and assigns the legal and organizational levels the same weight as the technical ones [14]. The cross-border health services infrastructure is the practical embodiment of this approach, establishing the procedure for transmitting the patient summary and the electronic prescription between different national systems [15]. The practice of defining a minimum mandatory data set has spread widely as an effective means of unifying the content of exchange [16].

The economic dimension of interoperability has also been addressed in the scientific literature: it has been substantiated that the free movement of records between institutions reduces duplicated examinations and raises the managerial value of data [17]. The review of the sources showed that studying the levels separately is widespread, whereas expressing their interdependence within a single methodological scheme occurs comparatively rarely.

RESEARCH METHODOLOGY

The research rested on comparative-analytical methods and on structural modelling. The source base comprised open technical specifications, international framework documents, peer-reviewed scientific publications and national regulatory acts. Requirements relating to interoperability were extracted from the text of each source and distributed across four levels.

The characteristics of the software product quality model were adopted as the criterial basis for assessment by level: functional suitability, portability, reliability and maintainability [18]. The contemporary methodical approach to expressing clinical content in machine-readable form was drawn upon in defining the practical measures of the semantic level [19]. Reports of international cooperation platforms created the context for comparing national experience across the levels [20].

The methodological scheme was formed in five stages. At the first stage a map is drawn of the institution's existing systems and of the data flows between them. At the second stage the exchange scenario is determined for each flow and a matching integration profile is selected. At the third stage a terminological mapping table is prepared. At the fourth stage the technical solution is verified in a test environment. At the fifth stage the quality of exchange is assessed against the criteria and the results are consolidated in organizational documents.

Reliance solely on open and verifiable sources ensures that the results can be re-examined. The choice of qualitative analysis follows from the regulatory and technical nature of the object: the level of interoperability is measured first through conformity with rules and only thereafter through quantitative indicators.

ANALYSIS AND RESULTS

Distributing the sources by level revealed the hierarchical nature of interoperability. Conformity at a lower level is a necessary but insufficient condition for conformity at a higher one: a functioning transmission channel does not guarantee that the content of the data will be interpreted identically. This logic was adopted as the principal tenet of the methodology.

The technical level covers network protocols, interfaces and authentication mechanisms; its indicators are connection stability and response time. The syntactic level concerns data formats and structures, and it is here that the resource-based specification [6] and the document architecture standard [8] are applied. The semantic level rests on terminological coding systems [9], [10] and also incorporates the dedicated standard for medical images [11]. The organizational-legal level establishes exchange rules, the consent procedure and the distribution of responsibility (Figure 1) [14].

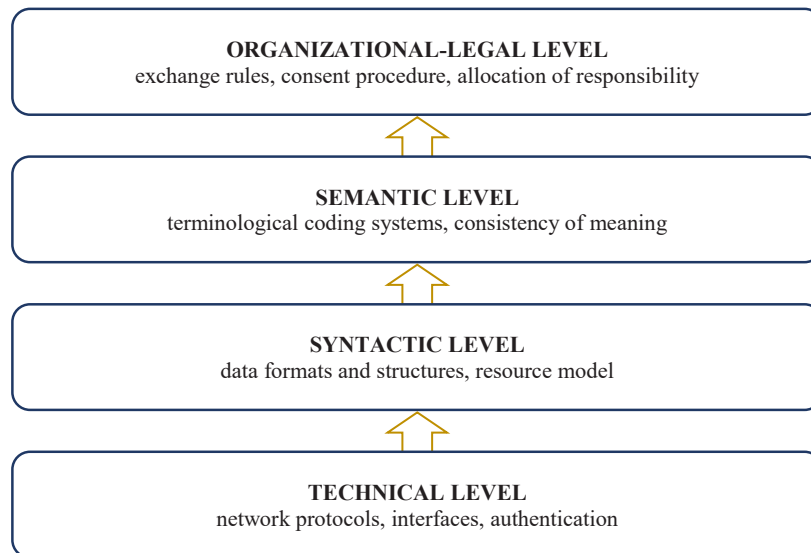


Figure 1. Levels of interoperability of healthcare information systems and their hierarchical interdependence¹

The standards base and the assessment criteria by level are summarized in Table 1. The table serves as the practical core of the methodology: whenever an integration project is planned, conformity is checked against the corresponding rows (Table 1).

Table 1
Standards base and assessment criteria by interoperability level²

Level	Content	Standards base	Assessment criterion	Source
Technical	Connection, transmission and authentication mechanisms	Web interface protocols; application-level open interface model	Connection stability; response time	[5], [7]
Syntactic	Conformity of data format and structure	Resource-based specification; clinical document architecture	Share of schema conformity; error-free transmission	[6], [8]
Semantic	Identical interpretation of the meaning of transmitted data	Clinical terminology nomenclature; observation codes; imaging standard	Share of coded records; coverage of the mapping table	[9], [10], [11], [12]
Organizational-legal	Definition of exchange rules and responsibility	Interoperability framework; cross-border service procedures	Existence of agreements; degree of compliance with rules	[14], [15], [16]

¹ Source: compiled by the author on the basis of [6], [8], [9], [10], [11], [14].

² Source: compiled by the author on the basis of the sources indicated in the table.

The procedure for applying the methodology at the institutional level was formed in the following sequence. A map of data flows is drawn first, and for each flow the exchange scenario is classified: internal inter-module transmission, inter-institutional transmission, or transmission to the central platform. At the next step an integration profile matching the scenario is selected and consolidated in an organizational document [13]. When the terminological mapping table is prepared, local codes are linked to the international nomenclature, while unlinked values are kept in a separate register and covered incrementally [9], [10].

The testing stage provides the quality guarantee of the methodology. During testing, the schema conformity of transmitted records, the share of coded fields and the description of returned errors are recorded. These indicators are linked to the characteristics of the software product quality model and tracked over time [18]. The practice of describing clinical logic in machine-readable form makes it possible to attach decision-support modules to the exchange flow [19].

The analysis identified three important dependencies. First, achievements at the semantic level depend directly on the stability of the syntactic level: where format mismatches persist, terminological work yields no practical result. Second, the solidity of the organizational-legal level raises the return on investment made at the lower levels, since formalized rules spare technical solutions from repeated reworking [14]. Third, regular observation of international experience sustains the pace at which national profiles are updated [20].

The legal preconditions for applying the methodology in the national context are in place. The tasks of creating a digital healthcare platform and introducing an integrated database complex allow exchange rules to be set centrally [1], while the document on deepening sectoral reform supports the incremental consolidation of institutional activity within a single information space [2].

CONCLUSIONS AND SUGGESTIONS

The research substantiated the possibility of interpreting interoperability as a single methodological construct. The four-level structure links technical solutions with organizational rules and provides a clear orientation for planning integration projects. The hierarchical dependence between the levels serves as the guiding principle in establishing the sequence of project work.

The base of open specifications constitutes the technological foundation of the methodology. The resource-based exchange model [6], the clinical document architecture [8], the terminological nomenclatures [9], [10] and the imaging standard [11] jointly cover every type of exchange between institutions, while integration profiles supply the order in which they are combined in concrete scenarios [13].

The recommendations are as follows. First, it is expedient to approve a list of mandatory integration profiles at the sectoral level and to update it periodically. Second, establishing a central service to maintain terminological mapping tables would secure the stable development of the semantic level. Third, it is advisable to make interoperability testing a compulsory stage in the acceptance of new information systems [18].

Fourth, introducing the practice of regularly recording exchange quality indicators in institutions would supply management decisions with evidence. Fifth, studying cross-border exchange experience makes it possible to align national profiles with international practice [15]. Sixth, approving a minimum mandatory data set adapted to national conditions unifies the content of exchange [16].

A promising direction for further research is the development of an index that measures conformity by level in quantitative terms and its testing across institutions. Such an index would create a basis for comparing the effectiveness of integration projects and for allocating resources purposefully.

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Proofreader: Xondamir Ismoilov
Layout and Designer: Hasan Maqsudov

2026. № 8

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