https://doi.org/10.33271/nvngu/2022-4/162

G. Zhanbirov[1],
orcid.org/0000-0001-8971-359X,
A. Toktamyssova[1],
orcid.org/0000-0002-9434-7413,
B. Mussabayev[1],
orcid.org/0000-0002-1794-7554,
Y. S. Tanachova[2],
orcid.org/0000-0002-7070-1748,
T. A. Zheldak[2],
orcid.org/0000-0002-4728-5889

1 – Academy of Logistics and Transport, the Republic of Kazakhstan
2 – Dnipro University of Technology, Dnipro, Ukraine, e-mail: tzheldak@gmail.com

DIGITALIZATION APPROACH IN EDUCATION BASED ON APPLYING THE NETWORK READINESS INDEX AS THE UNIVERSAL METRIC

Purpose. To achieve an integrated approach to assess the readiness of a higher educational institution for digital transformation in the form of a multi-criteria analysis of the university activities and development.

Methodology. The approach of educational institutions rating assessment, based on a hierarchical criterion, called the Index of Information and Communication Technologies Development (hereinafter ICT Index) is proposed in the work. The approach is considered to be an analogy of the Networked Readiness Index developed by the Information Technology Group at Harvard University's Center.

Findings. It is proposed to follow the approach of the ICT Index calculating as a universal metric for the digital transformation level assessment of educational institutions based on the Networked Readiness Index, namely to adopt abstract categories of top-level criteria and to average the values of hierarchical nesting.

Originality. The approach originality consists in the weight coefficients input at any level of the hierarchy. In addition, the approach provides a flexible choice of the Index resulting scale for the most understandable interpretation of the results, as well as the universal mathematical apparatus development for Index calculating. The proposed mathematical apparatus can be easily modified for any specificity of an educational institution and its criteria.

Practical value. The use of the ICT Index for all educational institutions in Kazakhstan will solve the problems of automating processes to ensure training and expanding the technological capabilities of educational institutions for modifying the forms of education at the state level by bringing the assessment indicators of all objects to a single scale.

Keywords: *education, digitalization, Networked Readiness Index, information and communication technologies, hierarchy criterion*

Introduction. The digital transformation of the education field in Kazakhstan started in the 90s. It was expressed in various forms and approaches from the origin till implementation. The problem of digitalization in the education sector nowadays consists of two key aspects:

1) automation of the education provision processes;

2) expanding the technological capabilities of educational institutions to modify the forms of education.

The first significant steps in the digital transformation process were implemented due to international cooperation, which later also acquired a modernized form, familiar to everyone as an online format for information exchanging. The experience gained by domestic specialists was used to expand the technological capabilities of educational institutions. At the same time, the development of new technologies, as well as their introduction at local levels, did not improve the quality of education at the state level.

One of the most effective modern practices on the path of education digital transformation is considered to be in the form of interaction with world organizations that provide not only opportunities for international communication, but also resource bases for the further use. A striking example is the large-scale Eurasian project "Modernization of higher education in Central Asia with the use of new technologies" (HiEdTec) of the Erasmus + program, founded in 2018. The Innovative Eurasian University, the L.N. Gumilyov Eurasian National University and Almaty Technological University were program participants from Kazakhstan.

The issues discovered during processes automation for the education provision are considered to be complex enough at the moment. To solve them, it is necessary to apply a systematic approach not only at the level of the educational institution, but also at the state one. The interaction of these two institutions has a bureaucratic form, which results in a long ineffective process, since the digitalization of the state administrative mechanisms has not yet been completed. The current status of this process is reflected in the state program "Digital Kazakhstan", approved in December 2017. Its term will have been expired by 2022. Following the logic of this program, digitalization is intended to become an infrastructural and technological basis for optimizing both the operating of the government and the hierarchically lower state structures. The optimization result is expected to influence the information and communication technologies (hereinafter ICT), which is determined every year by the World Economic Forum together with the International Business School INSEAD in the form of a rating through the so-called Index of Countries Readiness for a Networked Society.

The Index is calculated basing on sub-indices in the four areas: technology, people, governance and influence. Each of the categories has its own criteria sub-indices, normalizing the scales of the nested levels from the lowest to the highest ones. In this article, the described approach is proposed to be transferred to assess the Index of Readiness of Educational Institutions for Network Integration. Applying of the Index for all educational institutions of Kazakhstan is assumed to solve the problems of automating processes of education provision and expanding the technological capabilities of educational institutions. It is considered to be achievable due to identification of strengths and weaknesses among areas, improvement of one universal assessment that leads to comparison possibility.

Literature review. The attempt to apply the approach based on the network readiness index (NRI) for the purpose of educational institutions ranking is discussed in detail in [1]. According to the authors' opinion, the uniformity of the weights of all criteria and sub-criteria in the final rating is considered to be the key disadvantage of this approach. In the study, the authors demonstrate that the individual indicators, included into the sub-criteria, are related and influence each other. Thus, the weight introduction for the highest level criteria is proposed. Particularly, increasing the weight of the indicators, related to the business readiness of the educational institution, are assumed to be more vital than increasing those ones, which are influenced by government performance. The reason for this suggestion is explained by the issue of enough opportunities lack in terms of educational institution for its digitalization attempts, although working conditions and requirements set by the government have a significant impact on the NRI rank.

Another example of the application of a state object multi-criteria hierarchical assessment is described in [2]. In contrast to [1], the authors focus on company's reputation, instead of digital readiness, as an analyzed characteristic, emphasizing that reputation is one of the most important values of any company, especially in the era of society digitalization. Accordingly, approach was called as the Digital Reputation Index. It takes into account the degree of positive or negative reviews of a company on social media, third-party websites, blogs, and wikis. The work also implemented diagnostics of the proposed Index in order to assess its degree of reliability.

The state development and prospects stages of Kazakhstan digital transformation are documented in [3], where five key directions are identified: digitization of the economy branches, transition to the digital state, implementation of the digital Silk Way, evolution of the human capital assets, innovative ecosystem formation [4, 5]. The educational sector is implicitly included in the program, and its problems are partially reflected on the human capital assets direction, namely, on increasing the population digital literacy. However, the aforementioned problematic aspects of education and science managing process automation, as well as expanding the technological capabilities of educational institutions are not focused on in the "Digital Kazakhstan". As a result, there are no developed state methods for the assessment of the educational institutions readiness for network integration.

The Covid-19 epidemic as a driving force in the transition to digital education is discussed in a study [6], where the authors assess the impact on the readiness to digitalize the educational processes in Norway and Kazakhstan. The main purpose of the study is to examine the impact on distance learning satisfaction of students from different countries with different levels of personal safety, health and amenities. The results of the study represent the interest in terms of assessing the readiness of different countries for full digitalization of educational services.

Obviously, the educational process in such an unstable background should have been regulated by the integrated worldwide organization. This is confirmed by the extraordinary session on October 22, 2020 of the Global Meeting on Education, organized by UNESCO in cooperation with the governments of Ghana, Norway and the United Kingdom, whose declaration is displayed in the source [7]. Attention is focused on the fact that obtaining a quality education is one of the human rights, and the needs of students must be met even in such difficult conditions of state economies. Consequently, several organizational and financial decisions were made regarding many UN educational programs, in particular the Education 2030 project [8].

However, the time, devoted to decision making in the context of education process modifying with the aim of students' interest protection, was too limited in order to assess the level of education service providing and students readiness status. Despite of information lacking at that period and complexity of students' readiness status metrics generation, nowadays some themed research studies, [9 and 10] in particular, have already been published. The focus of [9] is devoted to assessing the impact of students' readiness status to use ICT and other network resources on their creative abilities, including in the processes of non-formal learning. The inclusive component of the education informatization process is emphasized due to the teachers and students involved into the learning process in the form of a dialogue. The latter is considered to be more effective than the traditional approach from lectures and seminars. Research findings suggest that university teachers should be encouraged to undertake more complex activities, especially activities based on the interaction with peers, collaborative learning and the use of ICTs to plan and organize their own learning processes. The authors of the study [10] outline such an important aspect as students' perception of the ICT introduction in higher education.

The relevance of the educational and scientific digital transformation activities was determined by the traditionally not making progress in time development of the business sector since industrialization, which led to the adoption of the management and control processes approaches [11, 12]. An example of the adoption phenomenon is represented in the publication [13], which describes an integrated approach to assess the readiness of a higher educational institution for digital transformation in the form of a multi-criteria analysis of the university activities and development in four directions: the maturity of the organization's architecture; maturity of the management process approach; available human resources and competence of employees; correspondence of the used financing instruments to the needs and tasks of digital transformation.

A number of scientific works are devoted to certain aspects of assessing the readiness of the educational process for digital transformation. In particular, the problem of global ICTs and their application in sustainable education is explored in [14]. It is emphasized that along with modern wireless technologies, provision of educational institutions and workplaces with traditional wired access to the global Internet will remain highly relevant in the near future. The latter is considered as the main source of information, including for self-education for both trainees and teachers. Assessments of the digital transformation inheritance in education are also assigned to the research [15]. The process of education transformation in the country as one of eight warehouses of the backbone digitalization programs are studied by scientists from Vietnam. The authors outline 22 indicators for assessing the readiness of both the educational pledges, as well as the students themselves, to digital transformations at the university. The mutual influence of the parameters on each other is analyzed. In addition to that, the statistically sound analysis of the previous test results is applied.

Based on the Education process classification framework from the APQC association [16], the university process system was divided into three abstract groups: development processes, main activity processes and auxiliary processes, which in total contain 12 categories. Collectively, building blocks are used to assess the maturity of an organization's architecture.

The influence of individual indicators and their weights in complex multi-criteria assessments are the subject of research in many articles. For instance, the authors of the study [17] consider the traditional German test for knowledge of digital competencies D21-digital-index, which is used both in higher educational institutions and in vocational colleges. It has been statistically proven that the individual dimensions included in the synthetic index must have different weighting factors.

The development of this approach can be considered the study [18], where the educators' preparedness to the social problems, caused with the digital transformation in academic community, applying the covariance based-structural equation modeling (CBSEM), is researched. The authors studied the related to digital transformation factors influence on each other and focused on the evidence of the dependency between the digital literacy, related to the academic library, and the individual informatization success during digital changes in the academic community. Digital transformation of libraries is emphasized as one of the key factors in improving informatization preparedness level. Such a reason is contrasted to the greater number of early research studies, where the main criteria for readiness before digital transformation are called business criteria, particularly in [19].

The issue of higher education institutions ranking in Kazakhstan is discussed in detail in [20]. The author accentuates the problem of combining the higher education institutions from the post-Soviet space with the world educational ones due to the discrepancy between the indicators adopted to assess the ranking of Europe and the United States universities. At the same time, the Covid-19 pandemic has significantly changed the world rankings, mostly moved them to the side of the possibility to provide remote digital services.

As shown in [20], despite the general discrepancy in the names of evaluation indicators and the dimensionality of measurement scales, most world ratings are isomorphic to each other. Therefore, it is proposed to perform the rationing of indicators on a certain dimensionless scale and to move from the traditional post-Soviet methods for rating formation to the universal one.

As an example of such universal rating, we may consider the NRI, taken as a basis in this study.

Since 2002, the Network Readiness Index (hereinafter NRI) has been published annually within the framework of the Global Report on Information Technology of the World Economic Forum. The index is presented as a holistic framework for assessing the multifaceted impact of ICT on society and the development of nations [21]. The Index was developed by the Information Technology Group at Harvard University's Center for International Development.

The index was reviewed in 2019 by its founders and co-editors Sumitra Dutta and Bruno Lanvin, now sponsored by the Portulance Institute, to reflect how technology and people should be integrated. As part of an effective governance structure, in order to have the right impact on our economy, society and the environment. The 2020 NRI is the second edition of this updated methodological regime and is geared towards digital transformation. It ranks 134 countries, basing on their performance across 60 variables [22].

Let us consider the structure of the Index in more detail, shown in Fig. 1 [23]. It is hierarchical with two levels of nesting. The outer layer includes four categories: technology, government, people, influence.

The *2nd* level of nesting includes 16 sub-criteria from the category of technologies, 14 from the category of government, 16 and 14 from the categories of people and influence, respectively. It is proposed to drill into each criterion and sub-criterion.

Since 2002, the Network Readiness Index (hereinafter NRI) has been published annually within the framework of the Global Report on Information Technology of the World Economic Forum. The index is presented as a holistic framework for assessing the multifaceted impact of ICT on society and the development of nations [21]. The Index was developed by the Information Technology Group at Harvard University's Center for International Development.

The index was reviewed in 2019 by its founders and co-editors Sumitra Dutta and Bruno Lanvin, now sponsored by the Portulance Institute, to reflect how technology and people should be integrated. As part of an effective governance structure, in order to have the right impact on our economy, society and the environment. The 2020 NRI is the second edition [22] of this updated methodological regime and is geared towards digital transformation. It ranks 134 countries, basing on their performance across 60 variables.

The purpose of the study is to achieve an integrated approach to assess the readiness of a higher educational institution for digital transformation in the form of a multi-criteria analysis of the university activities and development.

Methods. Let us consider the structure of the Index in more detail, shown in Fig. 1. It is hierarchical with two levels of nesting. The outer layer includes four categories: technology, government, people, influence.

The *2nd* level of nesting includes 16 sub-criteria from the category of technologies, 14 from the category of government, 16 and 14 from the categories of people and influence, respectively. It is proposed to drill into each criterion and sub-criterion.

Technology is at the heart of the network economy. This pillar, therefore, seeks to assess the level of technology that is a sine qua non for a country's participation in the global economy. The following three sub-pillars have been identified for that purpose [22]:

1. Access: The fundamental level of ICT in countries, including on issues of communications infrastructure and affordability.
2. Content: The type of digital technology produced in countries, and the content/applications that can be deployed locally.
3. Future Technologies: The extent to which countries are prepared for the future of the network economy and new technology trends such as AI and Internet of Things (IoT).

The availability and level of technology in a country is only of interest insofar as its population and organizations have the access, resources, and skills to use it productively. This pillar is therefore concerned with the application of ICT by people at three levels of analysis: individuals, businesses, and governments [22].

1. Individuals: How individuals use technology and how they leverage their skills to participate in the network economy.
2. Businesses: How businesses use ICT and participate in the network economy.

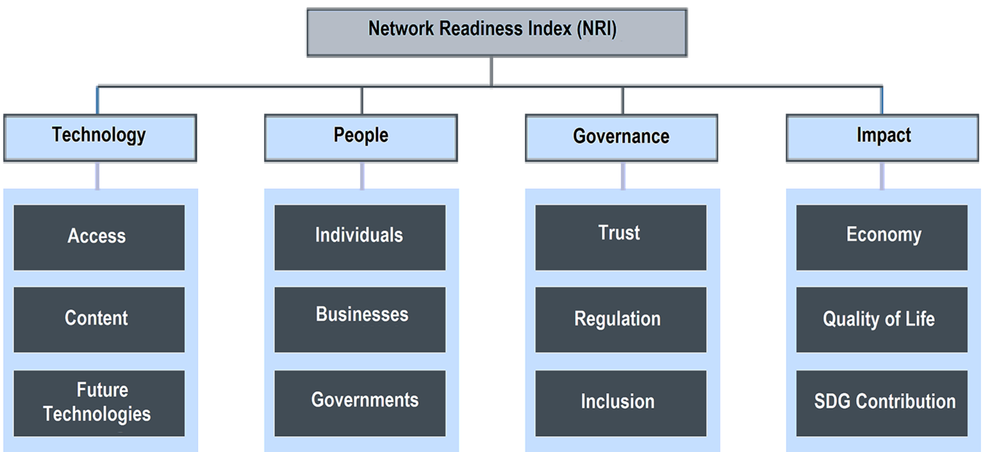

Fig. 1. General structure of the Network Readiness Index [23]

3. Governments: How governments use and invest in ICT for the benefit of the general population.

A country's network readiness does not take place in a vacuum and is a function of the national context within which people operate. Thus, this pillar seeks to capture how conducive the national environment is for a country's participation in the network economy, based on issues of trust, regulation, and inclusion [22].

1. Trust: How safe individuals and firms are in the context of the network economy, as reflected by an environment conducive to trust and the trusting behavior of the population.

2. Regulation: The extent to which the government promotes participation in the network economy through regulation.

3. Inclusion: The digital divides within countries where governance can address issues such as inequality based on gender, disabilities, and socioeconomic.

Ultimately, readiness in the network economy is a means to improve the growth and well-being of society and the economy. This pillar, therefore, seeks to assess the economic, social, and human impact of participation in the network economy [22].

1. Economy: The economic impact of participating in the network economy.

2. Quality of Life: The social impact of participating in the network economy.

3. SDG Contribution: The impact of participating in the network economy in the context of the SDGs – the goals agreed upon by the UN for a better and more sustainable future for all. The focus is on goals where ICT has an important role to play, including such indicators as health, education, and environment.

The computation of the NRI is based on successive aggregations of scores, from the indicator level (i.e., the most disaggregated level) to the overall NRI score. In general, the unweighted arithmetic mean has been used to aggregate individual indicators within each sub-pillar, sub-pillars within each pillar, and the pillars comprising the overall index.

In this paper it is proposed to follow the approach of the Information and Communication Technologies Development Index (hereinafter ICT Index) calculating as a universal metric for the digital transformation level assessment of educational institutions based on the NRI, namely:

1) to adopt abstract categories of top-level criteria;

2) to average the values of hierarchical nesting.

The novelty of the approach lies in additional add-ons:

1) to apply weight coefficients at any level of the hierarchy, that leads to the mathematical apparatus customizing;

2) to find the most flexible resulting scale of the Index for the most comprehensible results interpretation;

3) to develop the universal mathematical apparatus that can be easily modified for any specificity of the educational institution and its criteria.

It is assumed that the requirements for the weighting factors and the criteria creation for the internal model levels are to be created by the state unit responsible for the digital transformation implementation and control. Also, there is no exclusion to apply the ICT Index for the educational programs and universities accreditation.

A mathematical apparatus is proposed for calculating the ICT Index, based on the NRI calculation algorithm according to the following algorithm. The ICT Index calculation is performed with the formula

$$I = \sum_{i=1}^{4} w_i \cdot p_i \Bigg/ \sum_{i=1}^{4} w_i, \tag{1}$$

where P_i is pillar value obtained as a result of criteria convolution (takes on a value from 0 to 1); W_i is pillar significance value, chosen on any applied scale ([0...1]; [1...10]; [0...100], etc.); i is the number of the top-level criterion, taking on the value $i = 1{-}4$ – according to the number of top-level criteria.

It should be noted that the selection of weights is not a mandatory requirement for the calculation approach applying. Theoretically, it seems possible to assume the equivalence of the evaluation criteria. Then for all pillar significance W_i value will take on the value 1, automatically transforming expression (1) to the form

$$I = \sum_{i=1}^{4} P_i \Big/ 4, \tag{2}$$

which means the ICT Index value is determined as the arithmetic average over all pillars.

The values of each pillar are calculated analogically

$$P_i = \sum_{j=1}^{m} \lambda_j \cdot y_{ij} \Bigg/ \left(m \cdot \sum_{j=1}^{m} \lambda_j \right), \tag{3}$$

where i is a pillar number, $i = 1{-}4$; j is a sub-pillar number, $j = 1{-}m$; m is a sub-pillar quantity included into a pillar; λ_j is sub-pillar significance value, chosen on any applied scale ([0...1]; [1...10]; [0...100] ect.); y_{ij} is sub-pillar value resulting from the basic pillars convolution (takes on a value from 0 to 1).

The evaluation of the lowest nesting features is determined by the formula

$$y_{ij} = \sum_{k=1}^{t} \mu_k \cdot x_{ij,k} \Bigg/ \left(t \cdot \sum_{k=1}^{t} \mu_k \right), \tag{4}$$

where μ_k is basic pillar significance value, chosen on any applied scale ([0...1]; [1...10]; [0...100] ect.); y_{ij} is sub-pillar value, which can be expressed as a logical or numeric type, taking on a value from 0 to 1; i is a pillar number, $i = 1{-}4$; j is a sub-pillar number, $j = 1{-}m$; m is sub-pillar quantity included into a pillar; k is a basic pillar number, $k = 1{-}t$; t is basic pillar quantity included into a sub-pillar.

The weight coefficients in (3, 4) can be specified on an arbitrary scale similarly to the calculation (1) or be chosen equal.

Considering formulas (1–4), it is proposed to evaluate the ICT Index on a scale from 0 to 1. It provides a few advantages:

1) ranking the objects under consideration with a given accuracy (it is necessary to choose the number of the decimal place to be considered), that eliminates the problem of a discreteness high level and the impossibility of distinguishing between the objects of the same group under study;

2) values of any type, using as the basic pillar assessment can be normalized to a scale from 0 to 1;

3) simple division into semantic categories of any order.

A hierarchical structure of the ICT Index is proposed, as well as its calculation with two levels of nesting using the example of an abstract university (Fig. 2). The structure contains an abstract categorization of the 1st level of nesting, similar to the NRI model, and the *2nd* level is selected according to the nature and problems of the evaluated object in terms of the semantic context.

For instance, in a typical university the "Technology" pillar demonstrates the availability of the necessary conditions and systems for the learning process conducting within the university digital transformation, both at the present time and further. The sub-criteria of this pillar in more detail are presented below with a description of the aspects covered by each feature.

1st sub-pillar "Access" is a group of fundamental indicators that determine the very existence of a smart university, its network integration.

1.1.1. Internet access – coverage of computer workstations with Internet access.

1.1.2. Free Wi-Fi – coverage of the university territory by a wireless broadband Wi-Fi network with registration according to the university id-card.

1.1.3. Equipping with computer workstations – the degree of access to a PC (digitalization of jobs) for employees and students.

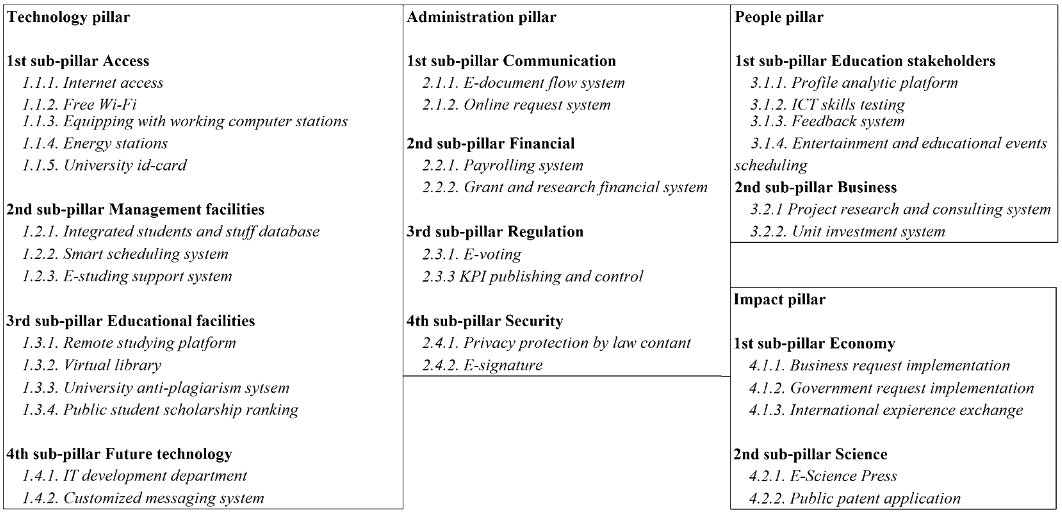

Fig. 2. Proposed ICT Index structure for educational institutions

1.1.4. Energy stations – availability of stations (stationary places) for device recharging. As all gadgets depend on batteries to work.

1.1.5. University id-card – personal identification at all technological levels of university systems.

2nd sub-pillar "Management facilities" – a group of indicators that assesses the ability for learning process digitalizing.

1.2.1. Integrated students and stuff database – a universal, normalized database that stores all documentary and tracking information about students, teachers and university staff.

1.2.2. Smart scheduling system – schedule developing and adjusting work automatically, basing on the E-studying support system.

1.2.3. E-studying support system – automation of the educational and methodological processes, accounting and monitoring of student progress, as well as planning the educational process.

3rd sub-pillar "Educational facilities" – a group of indicators that demonstrates the ability of switching to the online form of education, while having access to the necessary materials, anti-plagiarism control; follow the learning outcomes in the ranking.

1.3.1. Remote studying platform – a virtual space for conducting online classes, where educational materials are structurally provided, assessment is carried out, and knowledge is monitored. The system is integrated with students and stuff database, E-studying support system, Smart scheduling system.

1.3.2. Virtual library – a virtual space with electronic versions of educational, reference, methodological literature, as well as other digital information resources.

1.3.3. University anti-plagiarism system – a software implemented algorithm that checks the input information originality relatively to the existing objects in the depository (archive) of the university.

1.3.4. Public student scholarship ranking – student ranking by academic performance with the option of automatically determination of the scholarship holders list.

Finally, the *4th* sub-pillar "Future technology" is a group of indicators that demonstrates the potential of ICT Index improving in the future (a kind of development indicator). It includes the following features:

1.4.1. IT development department – the presence in the university structure of the department responsible for the implementation and support of the digital transformation process.

1.4.2. Customized messaging system – the presence of an information exchange system for students and university staff, integrated with the University id-card, Smart scheduling system.

The "Administration" pillar demonstrates the level of technology use in the university management. The sub-criteria of this group are considerably significant as their assessments are to prove existing of the university's tools, using for operations transparency and corruption fight.

1st sub-pillar "Communication" is a group of indicators that allows evaluating the work with a template workflow, namely:

2.1.1. E-document flow system – creation, exchange, distribution and internal university documentation accounting documentation without paper copies; integrated with E-signature, University id-card, E-studying support system.

2.1.2. Online request system – development of supporting documents for students and university staff through an e-request; integrated with E-signature, University id-card, Smart scheduling system.

2nd sub-pillar "Financial" – a group of indicators that assesses whether monetary transactions are to be automated functioning. It includes:

2.2.1. Payrolling system – automated cash payments to employees, students, intra-structural and contractors, integrated with the University id-card, E-studying support system, E-document flow system, Online request system, E-signature.

2.2.2. Grant and research financial system – accounting and access to funds intended for work on grant projects, research work of internal departments; integrated with Payrolling system, E-document flow system, Online request system, E-signature, University id-card.

3rd sub-pillar "Regulation" is a group of indicators that assesses the ability to conduct online events with the voting option, as well as create and control the implementation of a university development strategy along the entire hierarchy. This sub-criterion also contains two features:

2.3.1. E-voting – a system for electronic votes recording during online events for university employees and students, including the election of a rector, deans, other officials, as well as changes in regulatory documents; integrated with University id-card, E-signature.

2.3.2. KPI publishing and control – a system of KPI developing, managing and tracking, intended on employees along the entire vertical hierarchy, integrated with the University id-card, E-signature, Payrolling system, Online request system.

The last, *4th* sub-pillar "Security", is a group of indicators that assesses the possibility of identifying employees and students, as well as legal control of activities. The features are attributed for it:

2.4.1. Privacy protection by law content is an online system of obtaining legal assistance for students and employees in any areas of their interests.

2.4.2. E-signature is a digital unique file confirming identity, integrated with the University id-card.

The "People" pillar demonstrates the availability of data collecting and processing technologies by individual, the employees' and students' awareness about multi-topic events, as well as substantive interaction with external stakeholders. This top-level criterion consists of two sub-criteria and six attributes.

1st sub-pillar "Education" stakeholders is a group of indicators that determines the ability to collect and store information by the individual activities, receive feedback, and inform about various events.

3.1.1. Profile analytic platform – a system for data collecting and analyzing based on the intra-university activities of an individual, with an automatic system for recommendation letters mailing, as well as person profile creating, integrated with the University id-card.

3.1.2. ICT skills testing – a set of test tasks to determine the level of digital literacy for all employees and students at the university, integrated with the University id-card.

3.1.3. Feedback system – a system for launching and processing feedback forms, integrated with all electronic systems of the university.

3.1.4. Entertainment and educational events scheduling – a calendar system with automatic alerts for upcoming events, integrated with the University id-card.

2nd sub-pillar "Business" – a group of indicators that assesses the possibility of releasing human and project potential with the attraction of investment funds.

3.2.1 Project research and consulting system – a tracking system of developments, patents, research based on intra-university structural divisions, available for viewing by representatives of the business environment for commercial purposes. Access to the storage of information is provided by the authors of intellectual property. The system is integrated with university id-card, E-signature, Profile analytic platform.

3.2.2. Unit investment system – profile analytic platform data dubbing system with a filter option by the criterion of owner permission to participate in selection tour with the aim to develop the individual potential with the attraction of external investments.

Finally, the "Impact" pillar criterion assesses the degree of smart university performance on the state spheres of the economy and science. There are five indicators, combined into two sub-criteria.

1st sub-pillar "Economy" is a group of indicators that assesses the possibility of qualified personnel provision to state and private organizations, as well as implementation of the results achieved in cooperation with foreign universities.

4.1.1. Business request implementation – the university response rate to requests from external stakeholders, representatives of the business environment to fill the staff.

4.1.2. Government request implementation – the university response rate to government requests for staffing.

4.1.3. International experience exchange – the presence of the university's international activities with participation in offline internships, awareness of the practical and theoretical base of other countries, as well as exchange of experience in order to attract qualified specialists to debug intra-university processes.

2nd sub-pillar "Science" is a group of indicators that assesses the possibility to participate in research and scientific field of the university, and to defense the copyright university community members.

4.2.1. E-Science Press – electronic scientific publications, authored by university community members, with the ability to publish the results of scientific research both by students and staff of the university, and by external authors (on a commercial basis).

4.2.2. Public patent application – a system for searching and registering applications of copyright and patents, integrated with the University id-card.

Results. To calculate the ICT Index of an abstract academic institution, it is necessary to select appropriate scales for the basic characteristics measurement, which are to be used in formulas (1–4). At the same time, it is significant to highlight such basic pillar, belonging to the above-described structure in Fig. 2, which are measured by real relative values, as well as those that are of a logical nature.

It is proposed to consider the following indicators as real datatype values of an educational institution digitalization:

1.1.1. Internet access is a number showing the ratio of the number of working computer stations with Internet access to the number of all work computer stations.

1.1.2. Free Wi-Fi is a number equal to the ratio of the territory area covered with Wi-Fi connection to the total area of the educational institution. If the Wi-Fi zone exceeds the area of the training campus, the indicator is equal to 1.

1.1.3. Equipping with working computer stations – the ratio of workplaces equipped with computers to all workplaces in the university. If some employees have more than one computer workplace, and the ratio is greater than 1, the indicator value is assumed to be 1.

1.1.4. Energy stations – the ratio of the number of energy stations for every ten teachers and one hundred students. If the result is greater than 1, then the indicator value is assumed to be 1.

3.1.2. ICT skills testing is a number that illustrates the level of students testing coverage, equal to the ratio of university id-card users with passed ICT skills test to all university id-card users.

4.1.1. Business request implementation is a relative value equal to the ratio of the number of students who have taken the proposed job to the number of jobs allocated from business structures.

4.1.2. Government request implementation is a similar relative value equal to the ratio of the number of students who have taken the proposed job to the number of jobs allocated from government agencies.

The remaining 26 basic indicators are proposed to be considered as boolean variables taking values:

"1", if this indicator exists and implements the functionality specified in its description;

"0", if this indicator does not exist or does not fully implement the functionality (for example, a similar technology is still being developed or is at the implementation stage).

The examples of boolean values assessment for indicators are demonstrated below:

1. The university id-card indicator takes the value "1" if it is possible to identify a person at all technological levels of the university information systems, and "0" if the student ID is not used at all or is used partially – for example, for registration in the library and as a pass to the hostel.

2. Virtual library indicator takes the value "1" if any user of the university id-card has access to the virtual space with electronic versions of information sources, and "0" if, having a university id-card, a user must perform some kind of paper registration or physically be present in a specific room.

As an example, one of the universities was considered. The indicator values are shown in Table. The calculation of the ICT Index is illustrated on the example.

Considering all the indicators to be equivalent (as noted earlier, this approach can be revised at the request of the organization, conducting the assessment), using (4), the assessments by sub-criteria are calculated.

For the *1st* sub-pillar Access: $y_{11} = (0.75 + 0.86 + 0.76 + 0.74 + 1)/5 = 0.77$.

For the *2nd* sub-pillar Management facilities: $y_{12} = (1 + 1 + 1)/3 = 1$.

For the *3rd* sub-pillar Educational facilities: $y_{13} = (1 + 0 + 1 + 0)/4 = 0.5$.

For the *4th* sub-pillar Future technology: $y_{14} = (1 + 0)/2 = 0.5$.

For the *1st* sub-pillar Communication: $y_{21} = (1 + 0)/2 = 0.5$.

For the *2nd* sub-pillar Financial: $y_{22} = (1 + 0)/2 = 0.5$.

For the *3rd* sub-pillar Regulation: $y_{23} = (1 + 1)/2 = 1$.

Table

Indicator scores in terms of example calculation

Indicator	Value
1.1.1. Internet access	0.75
1.1.2. Free Wi-Fi	0.86
1.1.3. Equipping with working computer stations	0.76
1.1.4. Energy stations	0.47
1.1.5. University id-card	1
1.2.1. Integrated students and stuff database	1
1.2.2. Smart scheduling system	1
1.2.3. E-studying support system	1
1.3.1. Remote studying platform	1
1.3.2. Virtual library	0
1.3.3. University anti-plagiarism system	1
1.3.4. Public student scholarship ranking	0
1.4.1. IT development department	1
1.4.2. Customized messaging system	0
2.1.1. E-document flow system	1
2.1.2. Online request system	0
2.2.1. Payrolling system	1
2.2.2. Grant and research financial system	0
2.3.1. E-voting	1
2.3.2 KPI publishing and control	1
2.4.1. Privacy protection by law content	0
2.4.2. E-signature	1
3.1.1. Profile analytic platform	1
3.1.2. ICT skills testing	0.99
3.1.3. Feedback system	1
3.1.4. Entertainment and educational events scheduling	0
3.2.1 Project research and consulting system	0
3.2.2. Unit investment system	1
4.1.1. Business request implementation	0.94
4.1.2. Government request implementation	0.8
4.1.3. International experience exchange	1
4.2.1. E-Science Press	1
4.2.2. Public patent application	0

For the *4th* sub-pillar Security: $y_{24} = (1 + 0)/2 = 0.5$.

For the *1st* sub-pillar Education stakeholders: $y_{31} = (1 + 0.99 + 1 + 0)/4 = 0.75$.

For the *2nd* sub-pillar Business: $y_{32} = (0 + 1)/2 = 0.5$.

For the *1st* sub-pillar Economy: $y_{41} = (0.94 + 0.80 + 1)/3 = 0.91$.

For the *2nd* sub-pillar Science: $y_{42} = (1 + 0)/2 = 0.5$.

Among the second level sub-criteria, only 2 out of 12 take the value 1 – y_{12}, y_{23}; despite assessing most of the indicators take on 1 value in Table, which demonstrates the signs of digitalization are fulfilled.

Continuing the calculation, the sub-criteria within each of the criteria are to be equal and in order to move to a higher level, formula (3) should be applied. The index values by the top-level criteria will be equal to:

For Technology pillar: $P1 = (0.77 + 1 + 1 + 0.5)/4 = 0.82$.

For Administration pillar: $P2 = (0.5 + 0.5 + 1 + 0.5)/4 = 0.62$.

For People pillar: $P3 = (0.75 + 0.5)/2 = 0.63$.

For Impact pillar: $P4 = (0.91 + 0.5)/2 = 0.71$.

Continuing with the same principle at the top level, using formula (2), the ICT Index is calculated based on the chosen conditions and data from Table, considering all the criteria to be equivalent

$$I = (0.82 + 0.62 + 0.63 + 0.71)/4 = 0.695.$$

To illustrate the flexibility of the approach, the weighting coefficients of the criteria at the only upper level are proposed to be applied. For example, it is suggested to choose the scale from 1 to 10 and to assume pillar significance: Technology pillar – 10, Administration pillar – 8, People pillar – 6, and finally Impact pillar – 5.

Using formula (1), ICT Index comes gains the following result

$$I = (10 \cdot 0.82 + 8 \cdot 0.62 + 6 \cdot 0.63 + 5 \cdot 0.71)/(10 + 8 + 6 + 5) = 0.707.$$

The final value of the ICT Index, calculated according to formula (2) with equal priorities of the criteria turned out to be higher relatively to the ICT Index value, calculated according to formula (1), by $(0.707 - 0.695)/0.695 \cdot 100\,\% = 1.72\,\%$.

As it was demonstrated on the example calculations, it is easy to conclude that even a large difference in the weight of the criteria (two times) leads to an insignificant change in the final score. This indicates the stability of the proposed method to individual assessments by an expert performing the assessment and a weak influence on the result of subjective assessments.

Conclusions. The authors proposed an approach to assess the readiness of educational institutions for network integration based on the ICT Index. The latter is calculated based on sub-indices in 4 areas: technology, people, governance and influence. Each of the categories has its own criterion sub-indices, which are normalized by the scales from the nested level to the highest.

It is assumed that the use of the ICT Index for all educational institutions in Kazakhstan will solve the problems of automating processes to ensure training and expanding the technological capabilities of educational institutions for modifying the forms of education at the state level by bringing the assessment indicators of all objects to a single scale.

In the article the hierarchical structure for calculating the ICT Index, based on assessments of individual signs of the transition to digital learning is described. At the same time, it is proposed to create semantic levels of sub-pillars and indicators.

The calculation formula for the ICT Index assumes the assessment of 33 indicators, among which there are 7 real datatype ones, defined as relative values from 0 to 1, and 26 logical signs. Each indicator is given a numerical interpretation.

It is supposed that at each level of the hierarchy, the person or entity, conducting the assessment, can enter weights to account of the criteria significance, sub-criteria, or indicators. At the same time, the proposed methodology does not impose restrictions on the scale of the indicators and criteria significance, which can be arbitrary.

The presented formulas allow calculating the values of criteria, sub-criteria and the educational institution ICT Index by indicators. On the example of a separate educational institution, it is shown that the calculation formulas are resistant to the subjectivity of the weight coefficients significance in the assessment.

The next step in working with the ICT Index is to interpret its meaning. It is assumed that the state structural unit, which is going to be responsible for universal requirements development of the criteria, also provides the ICT Index scale interpretation. However, it is proposed to consider 3 categories:

1) "high level of digital transformation" in case the ICT Index value is arranged from 0.75 to 1;

2) “average level of digital transformation” in case the ICT Index value is arranged from 0.45 to 0.75;

3) “low level of digital transformation” in case the ICT Index value is arranged from 0.45 to 0.75.

Recommendations for increasing the ICT Index should be given to an educational institution primarily based on of such basic pillars whose values are less than 0.5.

References.

1. Wu, W.-W., Lan, L. W., & Lee, Yu-T. (2012). Exploring the critical pillars and causal relations within the NRI: An innovative approach, *European Journal of Operational Research*, *218*(1), 230-238. https://doi.org/10.1016/j.ejor.2011.10.013.

2. Seker, S. E., & Eryarsoy, E. (2015). Generating Digital Reputation Index: A Case Study. *Procedia – Social and Behavioral Sciences*, *195*, 1074-108. https://doi.org/10.1016/j.sbspro.2015.06.151.

3. *Digital Kazakhstan. Government Program* (2017). Retrieved from https://digitalkz.kz/wp-content/uploads/2020/03/%D0%A6%D0%9A-%D1%80%D1%83%D1%81.pdf.

4. Samorodov, V., Bondarenko, A., Taran, I., & Klymenko, I. (2020). Power flows in a hydrostatic-mechanical transmission of a mining locomotive during the braking process. *Transport Problems*, *15*(3), 17-28. https://doi.org/10.21307/tp-2020-030.

5. Taran, I.A., & Klimenko, I.Yu. (2014). Transfer ratio of double-split transmissions in case of planetary gear input. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu,* (6), 60-66.

6. Tleuken, A., Turkyilmaz, A., Unger, K., Tokazhanov, G., El-Thalji, I., Mostafa, M.Y., Guney, M., & Karaca, F. (2021). Which qualities should built environment possess to ensure satisfaction of higher-education students with remote education during pandemics? *Building and Environment*, 108567. https://doi.org/10.1016/j.buildenv.2021.108567.

7. Extraordinary Session of the Global Education Meeting, Education post-COVID-19: 2020 Global Education Meeting Declaration (2020). Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000374704.locale=en.

8. *Transforming Our World: The 2030 Agenda for Sustainable Development, United Nations Resolution A/RES/70/1* (2015). Retrieved from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

9. Lebeničnik, M., Pitt, I., & Istenič Starčič, A. (2015). Use of Online Learning Resources in the Development of Learning Environments at the Intersection of Formal and Informal Learning: The Student as Autonomous Designer. *CEPS Jornal*, *5*(2): *Higher Education Didactics*. https://doi.org/10.26529/cepsj.144.

10. Kozlova, D., & Pikhart, M. (2021). The Use of ICT in Higher Education from the Perspective of the University Students. *Procedia Computer Science*, *192*, 2309-2317. https://doi.org/10.1016/j.procs.2021.08.221.

11. Naumov, V., Zhamanbayev, B., Agabekova, D., Zhanbirov, Z., & Taran, I. (2021). Fuzzy-logic approach to estimate the passengers' preference when choosing a bus line within the public transport system. *Communications – Scientific Letters of the University of Žilina*, *23*(3),A150-A157.https://doi.org/10.26552/com.C.2021.3.A150-A157.

12. Taran, I., & Litvin, V. (2018). Determination of rational parameters for urban bus route with combined operating mode. *Transport Problems, 13*(4), 157-171. https://doi.org/10.20858/tp.2018.13.4.14.

13. Dolganova, O., & Mirzoyan, M. (2019). Multi-criteria assessment of the university's readiness for digital transformation. *Creative Economy.* https://doi.org/13.811.10.18334/ce.13.4.40560.

14. Hu, B., Noman, S.M., Irshad, M., Awais, M., Tang, X., Farooq, U., & Song, C. (2021). A pilot study of Global ICT strategy applications in sustainable continuing education. *Procedia Computer Science*, *183*, 849-855. https://doi.org/10.1016/j.procs.2021.03.009.

15. Pham, H., Tran, Que-Nhi., La, Gia-Long., Doan, Ha-My, & Vu, Tien-Duc (2021). Readiness for digital transformation of higher education in the Covid-19 context: The dataset of Vietnam's students. *Data in Brief*, *39*, 107482. https://doi.org/10.1016/j.dib.2021.107482.

16. *Education process classification framework (v.7.2.1). Houston: APQC* (2021). Retrieved from https://www.apqc.org/pcf .

17. Wild, S., & Schulze Heuling, L. (2021). Re-evaluation of the D21-digital-index assessment instrument for measuring higher-level digital competences. *Studies in Educational Evaluation*, *68*, 100981. https://doi.org/10.1016/j.stueduc.2021.100981.

18. Deja, M., Rak, D., & Bell, B. (2021). Digital transformation readiness: perspectives on academia and library outcomes in information literacy. *The Journal of Academic Librarianship*, *47*(5), 102403. https://doi.org/10.1016/j.acalib.2021.102403.

19. Tang, Y.M., Chen, P.C., Law, K.M.Y., Wu, C.H., Lau, Y-y., Guan, J., He, D., & Ho, G.T.S. (2021). Comparative analysis of Student's live online learning readiness during the coronavirus (COVID-19) pandemic in the higher education sector. *Computers & Education, 168*, 104211. https://doi.org/10.1016/j.compedu.2021.104211.

20. Anafinova, S. (2020). The role of rankings in higher education policy: Coercive and normative isomorphism in Kazakhstani higher education. *International Journal of Educational Development*, *78*, 102246. https://doi.org/10.1016/j.ijedudev.2020.102246.

21. Global Information Technology Report 2015 (2015). *World Economic Forum*. Retrieved from http://reports.weforum.org/global-information-technology-report-2015/network-readiness-index/ .

22. Dutta, S., & Lanvin, B. (2020). *The Networked Readiness Index. Portulans Institute*. Retrieved from https://networkreadinessindex.org/2020/.

23. THE NETWORK READINESS INDEX 2020 015. Accelerating Digital Transformation in a Post-COVID. Global Economy (n.d.). Retrieved from https://networkreadinessindex.org/wp-content/uploads/2020/10/NRI-2020-Final-Report-October2020.pdf.

Цифровізаційний підхід в освіті на основі застосування індексу мережевої готовності як універсальної метрики

Г. Жанбіров[1], *А. Токтамиссова*[1], *Б. Муссабаєв*[1], *Ю. С. Таначова*[2], *Т. А. Желдак*[2]

1 – Академія логістики та транспорту, м. Алмати, Республіка Казахстан

2 – Національний технічний університет «Дніпровська політехніка», м. Дніпро, Україна, e-mail: tzheldak@gmail.com

Мета. Досягнення комплексного підходу до оцінки готовності вищого навчального закладу до цифрової трансформації у формі багатокритеріального аналізу діяльності й розвитку університету.

Методика. У роботі запропоновано підхід до рейтингового оцінювання навчальних закладів за ієрархічним критерієм, що називається Індексом розвитку інформаційно-комунікаційних технологій (далі ІКТ-індекс). Цей підхід вважається аналогією індексу мережевої готовності, розробленого Групою інформаційних технологій Центру Гарвардського університету.

Результати. Пропонується використовувати підхід до обчислення ІКТ-індексу як універсальної метрики для оцінки рівня цифрової трансформації навчальних закладів на основі Індексу мережевої готовності, а саме прийняти абстрактні категорії критеріїв верхнього рівня та усереднювати значення ієрархічної вкладеності.

Наукова новизна. Оригінальність підходу полягає у введенні вагових коефіцієнтів на будь-якому рівні ієрархії. Крім того, підхід забезпечує гнучкий вибір результуючої шкали Індексу для найбільш зрозумілої інтерпретації результатів, а також розроблення універсального математичного апарату для обчислення Індексу. Запропонований математичний апарат легко модифікується під будь-яку специфіку навчального закладу та його критерії.

Практична значимість. Використання ІКТ-індексу для всіх навчальних закладів Казахстану дозволить вирішити проблеми автоматизації процесів для забезпечення підготовки й розширення технологічних можливостей навчальних закладів, модифікації форм навчання на державному рівні шляхом приведення показників оцінки всіх об'єктів до відповідного рівня.

Ключові слова: *освіта, цифровізація, індекс мережевої готовності, інформаційно-комунікаційні технології, критерій ієрархії*

The manuscript was submitted 19.12.21.