Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2020.vol7.no12.1133

Analysis of the Level of Technological Development and Digital Readiness of Scientific-Research Institutes

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Received: September 10, 2020 Revised: November 08, 2020 Accepted: November 16, 2020

Abstract

The purpose of this study is to analyze the level of science and technology development and digital readiness of scientific research institutes based on the author's assessment methodology (a set of evaluations and multifactorial indicators). Keeping with the previous literature, the research is caused by the novelty of the problem, which suggests dividing the literature review into two main research groups: theoretical background, which concentrates on the digital readiness definition, and the impact of digital readiness on science. Moreover, the scientific significance lies in the fact that proposed ideas in the research, developed theoretical and methodological provisions can significantly enrich theories related to the identification of the digital readiness of science and its consumers. Further, the research is devoted to the development of assessment methods of digital changes and analysis of the level of development of digital readiness of scientific research institutes, which is based on the author's assessment methodology (a set of evaluations and multifactorial indicators). The methodology provides an opportunity to build ratings of the digital readiness of scientific-research institutes to the formation and development of a digital economy. Obtained results show that the priority task in the current and the future period is to increase the authority and recognition of scientific organizations, the quality of scientific research, and the formation of demand for scientific products.

Keywords: Innovation, Digital Economics, Digital Readiness, Technological Development, ICT, Kazakhstan

JEL Classification Code: O14, O30

1. Introduction

The spread of the COVID-19 infection led to the declaration of a pandemic. This has affected the socio-economic development of many governments. The

Covid-19 pandemic has led to an inevitable surge in the use of digital technologies due to the social distancing norms and nationwide lockdowns. At the same time, the degree of participation of each country in the process of fighting the crisis largely determines the prospects for scientific and technological development of the country and its competitiveness. Therefore, one of the main issues is measuring science and technology progress. Besides, the development of information-communication technologies (ICT) has contributed enormously to all sectors of the economy such as production, trade industry, finance, science, business, and so on. Technologies give opportunities to create and disseminate data, information, and knowledge, ideas, to build and commercialize innovations. Thus, the need for quantitative estimation of science and technology progress including the influence of digital technologies is in great demand. The paper aims to analyze the level of science and technology development and digital readiness of the scientific research institutes (a set of evaluation and multifactorial indicators).

Before considering the indicators of assessment and conducting a quantitative measurement, special attention

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should be paid to the literature review of existing works on this issue, both international and national scientific literature. There is sufficient material that has become the source for the theoretical and methodological justification of this research. Some concepts and methodologies have been adopted, modified, and refined by new scientific communities. Scientific and technical progress is a complex, multi-faceted process of improving the efficiency of the economy, associated with the improvement of existing technologies and new production methods (Swanson, 1994; Beuningen, Ruyter, Wetzels & Streukens, 2009; Kireyeva, Abilkayir & Tsoy, 2018). The quantitative assessment of technological changes requires general integrated indicators of production efficiency and technological development (Snyder-Halpern, 2001; Lam et al., 2008; Son & Han, 2011). Besides, many studies have attempted to quantify the level of digital readiness (Parasuraman, 2000; Tilson, Lyytinen & Sørensen, 2010; James, 2011; Sedera et al., 2016; Horrigan, 2016). Some studies have linked digital readiness with electronic readiness, mobile readiness, and network readiness (Rojas-Méndez, Parasuraman, & Papadopoulos, 2017; Potnis & Pardo, 2011; Lin, et al., 2016). *Technology readiness* refers to people's propensity to embrace and use new technologies for accomplishing goals. Thus, digital readiness is defined as the willingness to create new innovative capabilities and applying these technologies to lead an individual, company, industry, and country to achieve their own goals faster and with tremendous results (Walczuch, Lemmink & Streukens, 2007).

Further, many scientific works described the impact of digital readiness on science and innovation. A large number of scientific papers are devoted to the study of problems of digitalization of economic and innovation processes (Jones, Jimmieson & Griffiths, 2005; Henfridsson & Bygstad, 2013; Alaaraj & Ibrahim, 2014; Satpayeva, 2017). Certain scientists explored innovations with the introduction of digital technologies to attract numerous and simultaneous adjustments in resources (Zittrain, 2006; Sirmon et al., 2011; Yoo, 2013). Special attention should be paid to research on project management in the field of science, and there is a tendency to identify the project with the development of innovation (Bresnen et al., 2003; Weeks et al., 2004; Lenfle, 2008; Lee & Xuan, 2019). However, many studies do not mention project management as a tool for highlighting innovation.

Accordingly, the term “digital readiness” has been chosen because it is cumulative and corresponds to the current era. Thus, the term “digital readiness” in the present refers to separate levels of digital readiness, which have been formulated differently by different indicators of technological innovations, for example, research and development expenses, the commitment of new funds for new equipment, the number of patents, and so on.

Nevertheless, the definitions of “readiness and “innovation” were examined by Klein & Kozlowski (2000) from the point of view of *organizational readiness for digital transformation*. They state that organizational readiness for digital innovation as an organization's assessment of its state of being prepared for effective production or adoption, assimilation, and exploitation of digital technologies for innovation. Thus, quite a lot of research has been devoted to the study of various aspects of technological development and digital readiness. However, there are no studies concerning methods for assessing the level of development of scientific and technological potential with a digital component.

The provided literature review has shown that there were few studies on a qualitative assessment of science and technology level of development with the use of digital components, especially in developing countries such as Kazakhstan, Russia, Belarus, among others. Most of the research is related and aimed at the application of the cross-analysis approach. Therefore, in developing countries such as Kazakhstan, such a study was practically not carried out and requires clarification. At the same time, an extremely small number of papers have been devoted to the cross-industry analysis of the level of the digital readiness of science, which, in our opinion, is a significant omission. Moreover, there are few studies, which describe the measurement of the contribution of science, algorithms, and methods for analyzing and evaluating its effectiveness, and adapting the experience of developed countries to the experience of developing countries is not adequate.

The majority of previous empirical studies into the analysis of the determinants of innovation are focused on larger analyzes such as the level of innovation potential (susceptibility of innovation, innovation activity), and therefore empirical studies like our research are rare. Thus, this study will aim to cover the above-mentioned gaps identified earlier in such studies by analyzing the level of technological development and digital preparedness at the level of scientific organizations using Kazakhstan as the data set.

Further, in this research, section 2 discusses relevant literature. Section 3 sets out the methods of scientific research. Section 4 presents an analysis and estimation results, and section 5 is the conclusion part.

2. Literature Review

2.1. Theoretical Background: Definition of Digital Readiness

The global trend in socio-economic development over the past few years has been towards the formation of a digital economy. The potential of the digital economy is largely

associated with the results of the creation and development of the information society. Historically, innovation with the introduction of technology needs a significant amount of resources (Swanson, 1994). As such, some scientists have established that the readiness to innovate with the introduction of technologies is directly proportional to the innovation results and inversely proportional to the innovation risks (Snyder-Halpern, 2001; Yousefi, 2011; Kireyeva, Abilkayir & Tsoy, 2018; Nurlanova et al., 2018). The movement of many countries towards the digital economy occurred almost simultaneously (Roztocki & Weistroffer, 2015), while the entry of countries on the path of information development occurred at different times, which determined significant differences in the level of their digitalization (Ardito et al., 2019). However, regardless of the time frame for the adoption of public policies in the field of the information society, the proposition that the digital economy is going to deliver development, prosperity, and growth has become almost conventional wisdom among policy-makers and innovators. Undoubtedly, a digital economy can lead to more trade, better capital use, and greater competition. It can promote efficiency and innovation as well as provide an inclusive platform for economic participation.

Digital readiness contains numerous meanings in the literature. Its leading definition is the willingness of individuals, organizations, and sections of the economy to introduce and apply innovative digital technologies to increase the benefits of these innovations. Horrigan (2016) applied the term “digital readiness” to measure the ability of adult people to use digital technologies in the United States. Quaicoe and Pata (2015) defined digital readiness as the readiness of teachers’ abilities, knowledge, and conviction to accept digital learning in the primary-secondary education system in Ghana. Punchihewa (2004) used this term in his study of the readiness of Sri Lankan Universities to implement electronic government. Other scientists used digital readiness in their study of the (e-government) digital readiness of correspondents in Malaysia (Harris, Ives & Junglas, 2012; Hamzah & Mustafa, 2014; Sederat et al., 2016).

Technology readiness can be viewed as a gestalt resulting from four personality dimensions: optimism, innovativeness, discomfort, and insecurity. According to Parasuraman (2000), these personality dimensions affect people’s tendency to embrace and use new technologies. Lam, Chiang, and Parasuraman (2008) investigated the impact of 4 dimensions on the time of online adoption by consumers and the variety of its applications, demonstrating that optimism, innovation, and insecurity significantly affect 2 behaviorally dependent variables in the expected direction. They also added that the impact of innovations on online adoption is relatively less than the impact of optimism and uncertainty. They developed hypotheses about the effects of the dimensions (innovativeness, optimism, discomfort, and insecurity)

of technology readiness on two key stages of Internet acceptance, adoption, and usage of different Internet-based activities, and test them through a two-stage model using U.S. consumer survey data. The findings show that these dimensions have significant enduring effects on the two stages at varying levels of perceived risk. Besides, certain researchers studied the relationship between four dimensions of technological readiness and IPTV application models, i.e. the degree of application of basic functions, the degree of application of innovative functions, and the variety of forms of application of innovative functions (Son & Han, 2011).

Technology readiness (TR) refers to people’s propensity to embrace and use new technologies. Nowadays, the proliferation of technology-based products and services brings consumers not only benefits but also frustration over the ineffective use of products and services. A key factor, therefore, in the diffusion and success of these products and services is how well-prepared consumers are for new technologies. Son & Han (2011) further examined how each dimension (optimism, innovativeness, discomfort, and insecurity) of TR influences consumer usage patterns, and how usage patterns affect repurchase intention through consumer satisfaction. The empirical results from IPTV users in Korea show that each dimension of TR has a significantly different influence on usage patterns. The findings show that usage patterns, particularly the use of innovative functions, have a significantly positive impact on consumer satisfaction and repurchase intention. They identified four groups of users, divided by the prevailing personality trait, while two factors are considered motivators for the use of new technologies, the other two are considered inhibitors:

Optimism: a positive view of technology. Religion in increasing the control, elasticity, and productivity of life with technology support.

Innovation: the desire to be the first to apply new technologies.

Discomfort: the need for control and the feeling of depression.

Insecurity: distrust of technology based on security and privacy judgments.

Meanwhile, the Queensland Department of trade and industry used this term to refer to the willingness of the industry in the state to develop the capabilities that the digital economy provides. Finally, digital readiness is the need to measure and compare the digital readiness of developing countries with the developed world (James, 2008; Tilson, Lyytinen & Sørensen, 2010; James, 2011; Kireyeva & Satybaldin, 2019; Tran et al., 2020). Apart from this, there are also differences in terminology related to digital readiness. Some people associate digital readiness with E-readiness, readiness for electronic business, readiness for electronic government, digital readiness, mobile readiness, network readiness, and generally technological readiness.

Differences in terminology make it difficult to develop models of digital readiness, which indicates that the only definition of digital readiness that is likely to be accepted is not available. Inconsistent implementation of concepts and models of digital readiness has led to the fact that the results of studies are not comparable and do not have all the chances to be applied to the formation of joint awareness or knowledge of digital readiness. As a result, it is necessary to strive for uniformity by identifying the basic components of all models (Rojas-Méndez, Parasuraman, & Papadopoulos, 2017; Potnis & Pardo, 2011; Lin, Lin, Yeh, & Wang, 2016).

The definitions of “readiness and “innovation” were examined from two leading points of view: the organization’s willingness to resist innovation, and the organization’s willingness to implement or guarantee innovation (Klein & Kozlowski, 2000; Weiner, Amick & Lee, 2008). This study focuses on the latter, assessing the organization’s readiness to innovate with the introduction of digital technologies. The concept of organizational readiness for innovation has had only limited attention in the literature (Snyder-Halpern, 2001; Tilson et al., 2010; Walczuch, Lemmink & Streukens, 2007). An extended review of readiness for innovation as a broad view is presented as (i) readiness is a position that is reached before the start of certain work concerning the mental, behavioral and structural readiness of organizations; (ii) readiness can be monitored at several levels and then reviewed at the personal, team, departmental, or organizational level (Grover, Fiedler & Teng, 1999); and (iii) to conceptualize the readiness of something else as a level of readiness in a continuum, rather than as a dichotomous variable “ready” or “not ready”.

In the provided study, innovations are available at the organizational level. In this way, this study defines organizational readiness for digital as an organization’s assessment of its state of being prepared for effective production or adoption, assimilation, and exploitation of digital technologies for innovation (see Figure 1).

Figure 1: The conceptual framework of organizational readiness for digital innovation

All concepts and models have measurement components of digital readiness that seem to rest on a personal level. In other words, developing a digital model for measuring readiness on a personal level is considered a basic or necessary task. This is still being performed by Parasuraman (2000) when she came up with the readiness technology by Lai and Ong (2010) when they came up with the readiness of employees for the e-business. This is still being performed by Parasuraman (2000) when she came up with the readiness technology by Lai and Ong (2010) when they came up with the readiness of employees for the e-business.

In accordance with the specificity of the branch, scientists still confirm the importance of using technology as an indicator of readiness for the implementation of the technology. In a study by Beuningen, Ruyter, Wetzels, and Streukens (2009), they say that a person’s willingness to apply self-service technology is considered an important variable for the study of a person’s predisposition to apply this technology. Ariff et al., (2012) still support this statement. They studied the implementation of Internet banking systems and noticed a significant impact on the ability of a person to use a computer in the direction of readiness for the introduction of internet banking systems.

In this way, digital readiness is oriented as a predisposition and willingness to switch to digital technologies and adopt them, as well as a willingness to make fresh innovative abilities, applying these technologies to lead a person, company, branch, and country to achieve their own goals sooner and with huge results. In accordance with this, in contrast to these studies, the creators will try to make it cumulative, so that the concept of digital readiness on a personal level can be applied in all sorts of contexts. Further, the term “digital readiness” is chosen because it is cumulative and corresponds to the current era. In particular, the whole term “digital readiness” in the provided note refers to separate levels of digital readiness, which are formulated in different ways by different methods.

2.2. The Impact of Digital Readiness on The Science and Innovation

The digital technologies give organizations with low capital intensity the chance to implement innovations in the same way as their inventive colleagues (Henfridsson & Bygstad, 2013; Tan, Tan & Pan, 2016), challenging the classic equation of innovation with its complexity and resource availability. Besides, the technology potential of organizations is said to have been boosted by the important rise in its usage, thanks to which technology became available to normal people as a product (Harris, Ives & Junglas, 2012; Satpayeva, 2017).

However, ignoring the proliferation, scalability, availability, and ease of use and deployment of digital technologies (Harris, Ives & Junglas, 2012), organizations are still fighting for the absolute implementation of innovative potential, and new ideas do not appear in the supply of goods or offer due to the unavailability of organizational readiness of science (Snyder-Halpern, 2001). For organizations to succeed in digital innovation, they need to unfreeze, preserve and re-preserve their resources, similar to the three-step model of change. As such, innovations with the introduction of digital technologies, as they say, are very complex. Besides, innovations with the introduction of digital technologies attract numerous and simultaneous adjustments in resources, personnel, culture, decision-making, communications, and fee systems (Zittrain, 2006; Sirmon et al., 2011; Yoo, 2013; Kireyeva, Abilkayir & Tsoy, 2018). Apart from this, the non-exclusivity of digital technologies, where competitors have every chance to imitate innovations, means that organizations are required to have the ability to change their resources and strategy configurations every day to achieve competitive excellence. It is also important to indicate that situations of digitization furor proved that not only modern technologies, but also decision-makers in the field of it, and organizational civilization play a decisive role in the implementation of innovations (Weill & Vitale, 2002).

Lindner and Wald (2011) proposed an interesting solution to address the issue of knowledge management and transfer. They created a model for organizing an integration project. Innovation cannot flourish without a reliable integration management system (Henfridsson, Mathiassen & Svahn, 2014). According to the system, the project management process is divided into a list of criteria that can then be measured.

The doctrine of organizational readiness for change (abbreviated as “readiness theory”) provides a comprehensive theoretical framework for developing an assessment of organizational readiness for digital innovation (Liljander et al., 2006; Crossan & Apyadin, 2010; Alaaraj & Ibrahim, 2014). However, the readiness doctrine is widely applied in scientific circles, and none of the previous studies were dedicated to directly organizational readiness for digital innovation. Nevertheless, it is recognized that there are a large number of factors that affect the creation or adoption, assimilation, and implementation of digital innovations (Nylen & Holmström, 2015). Abstract facets of the readiness doctrine are used to obtain a priori systems of the readiness model.

According to the doctrine of readiness and in accordance with the proposed views, “readiness for change” is considered a harbinger of successful implementation of difficult changes. In particular, organizational readiness for change refers to the commitment of members to change and

the productivity of change to bring about organizational change. According to Weiner, organizational readiness for change shows on the provision of mental and behavioral readiness to act (Weiner, Amick & Lee, 2008). It is not trivial to be ready for innovation (Nelson & Winter, 1977). Focusing on the literature on organizational change, it is postulated that organizations accept, assimilate and exploit innovations if the configurations are perceived as necessary (readiness) and the organization has important probabilities (Teng et al., 1998). More directly, the readiness doctrine provides a framework for obtaining appropriate systems for organizational readiness of science for digital innovations.

The researchers highlighted various aspects that affect the readiness for change. For example, some researchers emphasize the importance of an organizational culture that promotes change (Jones, Jimmieson & Griffiths, 2005). It is argued that implementing innovative products is one of the new topics in project management. Nevertheless, knowledge management, where learning based on projects, faces many challenges (Bresnen et al., 2003; Weeks et al., 2004; Lenfle, 2008; Lokuge et al., 2019; Lee & Xuan, 2019). The focus is on business drivers for a practical understanding of the knowledge used in the research. Besides, some researchers emphasize the importance of flexible organizational strategies, partnerships (for example, good working relationships), and organizational procedures for increasing readiness for change (Rafferty & Simons, 2006).

The development of digital technologies has an impact on all sectors of the economy: production, trade, finance, transport, etc. Technologies expand opportunities in various areas, provide an opportunity to create and distribute data, information, knowledge, ideas, and develop and commercialize innovations. It also provides the tools through which the concept of the digital economy can be implemented to fully integrate digital technologies, data management methods, and real economic processes at the level of states, industries, and firms.

Today digitalization indicators can serve as indicators of readiness for transition to the digital economy and predict significant changes in the economy. These transformations include reducing transaction costs, increasing the innovation activity of individual enterprises and organizations, and creating and applying modern business models. Therefore, this research aims to assess the digital readiness of science and its consumers in Kazakhstan.

Moreover, the scientific significance lies in the fact that proposed ideas in the research, developed theoretical and methodological provisions can significantly enrich theories and practice level of identification of science digital readiness and its consumers. In particular, there will be new methodological approaches used in the research, which will permit analysis and give scientific results.

3. Research Methods and Materials

Many works have attempted to quantify technological development and digital readiness. (Parasuraman, 2000; Blau & Shamir-Inbal, 2017; Chanyagorn & Kungwannarongkun, 2011). Among more commonly used comprehensive indicators of the development of digital technologies in the world are international indices such as ICT Development Index (IDI) (ITU, 2009) and Networked Readiness Index (NRI) (WEF, 2016). IDI measures the level, progress, and potential of ICT development in developed and developing countries, as well as the level of the digital divide between them based on three sub-indices: access to ICT, use of ICT, ICT skills. The network readiness index is estimated by 4 sub-indices: conditions for the development of ICT, readiness for the use of ICT, the use of ICT, the impact of ICT. Different index systems are different in the calculation methodology, structure, and the ratio of quantitative and qualitative indicators used. On one hand, the objectivity of the data obtained is ensured, and on the other, there arises the problem related to the complexity of evaluating and reducing indicators to a single index. The disadvantage of these indexes for assessing the development of digital technologies is that they are designed for use within the framework of cross-country analysis. However, digital technologies occupy the central place in updating key areas of the economy and activities, and are the catalyst for innovative processes in individual industries, increase labor productivity, and have other positive effects, while the inter-sectoral analysis of digital development is not widespread.

From our point of view, the important task is to develop a methodology for assessing the readiness of industries, in particular the field of science, to form a digital economy.

Therefore, we have proposed the methodology for assessing the level of the digital readiness of scientific research institutes. The methodological basis was IDI and NRI with their adaptation at the organization level. The Scientific Research Institute's Digital Readiness Index is proposed and calculated based on 4 criteria: equipment availability, software, human resources, digital skills, and consumers. For each criterion, several indicators have been compiled (see Figure 2).

To bring heterogeneous indicators to a single scale for assessing scores, we used the WEF scoring methodology. In particular, to convert the values of indicators to a point score on a scale from 1 to 7, the following formula is used (1):

$$6 \times \frac{(\text{indicator value} - \text{minimum value})}{(\text{maximum value} - \text{minimum value})} + 1 \quad (1)$$

For those indicators for which a higher value indicates the worst result, the transformation formula takes the following form (2).

$$-6 \times \frac{(\text{indicator value} - \text{minimum value})}{(\text{maximum value} - \text{minimum value})} + 7 \quad (2)$$

Herewith the values 1 and 7 correspond to the worst and best possible results, respectively.

Availability of PC; Degree of depreciation of PC; Availability of PC with the Internet access; Specialized digital equipment; Degree of depreciation specialized digital equipment.	Availability of periodical electronic editions in open access; Availability of other electronic publications in the public domain; Availability of website.
Availability of equipment	Consumers
Software	Personnel and digital skills
MS Office 2016, 2019; Microsoft Office 2000-2013 and earlier; Research software; Software for solving organizational tasks and electronic document management; Software for accessing the database; Training software.	Percentage of professionals trained in digital skills development over the past 5 years; Proportion of specialists with common digital skills; Proportion of specialists with special digital skills; Availability of programmers; IT management; The proportion of young scientists.

Figure 2: Criteria for Assessing Digital Readiness of Research Institutes

Table 1: Index of the Digital Readiness of Research Institutes: Indicators, Units, Weights, Formulas

No.	Indicator	Unit of measurement	Sub-index weight	Group weight	Formula
1	Availability of equipment	0,25	0,25		
1.1	Availability of PC	%		0,20	1
1.2	Degree of depreciation of PC	%		0,20	2
1.3	Availability of PC with Internet access	%		0,20	1
1.4	Degree of depreciation specialized digital equipment	%		0,20	2
1.5	Local area network	unit		0,20	1
2	Software		0,25		
2.1	MS Office 2016, 2019	%		1/6	1
2.2	Microsoft Office 2000-2013 and earlier	%		1/6	1
2.3	Research software	number of programs		1/6	1
2.4	Software for solving organizational tasks and electronic document management	number of programs		1/6	1
2.5	Software for accessing the database	number of programs		1/6	1
2.6	Training software	number of programs		1/6	1
3	Personnel and digital skills		0,25		
3.1	Percentage of professionals trained in digital skills development over the past 5 years	%		1/6	1
3.2	Proportion of specialists with common digital skills	%		1/6	1
3.3	Proportion of specialists with special digital skills	%		1/6	1
3.4	Availability of programmers	%		1/6	1
3.5	IT management	unit		1/6	1
3.6	The proportion of young scientists (under 35 y.o)	%		1/6	1
4	Consumers		0,25		
4.1	Availability of periodical electronic editions in open access	unit		1/3	1
4.2	Availability of other electronic publications in the public domain	unit		1/3	1
4.3	Availability of website	unit		1/3	1
	Total score				

Based on the selected indicators, the following model for rating the digital readiness rating of scientific organizations can be proposed (see Table 1).

The issue-driven analysis was based on primary data. The population of the study was 15 public scientific organizations. It comprised 14,6% of all Kazakhstani public scientific–research institutes. The sample includes scientific organizations of natural, agricultural, medical, social, and humanitarian sciences. In these organizations, the number of employed staff makes up 2699 people or 44% of the staff of public sector:

- 1) Institute of Mechanics and Machines Science named after Dzholdasbekov U.A. (IMMS);
- 2) National Centre on Complex Processing of Mineral Raw Materials of the Republic of Kazakhstan (NC CPMRM RK);
- 3) Institute of Mining Affairs named after Kunayev D.A. (IMA);
- 4) Institute of Ionosphere;
- 5) Fesenkov Astrophysical Institute (FAI);
- 6) National Center of Space Technique and Technology (NCSTT);

- 7) M.Aitkhozhin Institute of Molecular Biology and Biochemistry (IMBB);
- 8) Institute of Plant Biology and Biotechnology;
- 9) Kazakh Institute of Oncology and Radiology (KazIOR);
- 10) Kazakh Research Institute of Agriculture and Plant Growing (KazRIAPG);
- 11) Kazakh Scientific Research Institute of Animal Husbandry And Forage Production (KazSRIAHFP);
- 12) Kazakh Research Institute of Forestry and Agroforestry (KazRIFA);
- 13) Scientific and Production Center for Grain Management named after A.I. Baraev (SPCGM);
- 14) Institute of Oriental Studies named after R. Suleimenov;
- 15) Institute of Economics.

Primary materials were collected in 2019 using semi-structured interviews with chief scientific secretaries of research institutions, who possess all information about their organization, as well as materials were collected from human resources, accounting, and administration. All respondents were guaranteed to be anonymous; contributors' names and positions were removed. A content analysis of the websites of these scientific organizations was also conducted. Microsoft Excel was used for processing statistical data.

A different feature of the authors' methodological tool is the analysis of the level of technological development and digital readiness of scientific research institutes. The suggested method by the authors differs in availability and simplicity of calculation.

4. Results and Discussion

Availability of equipment. The method offered in the article is based on the evaluation of indicators of provisions of organizations with leading hardware/firmware systems, the level of automation, and the amount of expenditure on IT field development. Special mention should go to the primary concern of evaluation provision with necessary equipment; conditions for practical application of computer equipment and other digital tools; the possibility of open access to information channels of in-device internal networks, the internet world network, and media resources.

A significant differentiation of scientific organizations in terms of equipment availability level should be noted. Most surveyed scientific organizations have a high enough level of PC availability and internet access as well. Nevertheless, several organizations have very low indicators. They are institutes in the field of agricultural research (KazRIFA, KazSRIAHFP KazRIAPG, FAI, IMA) (see Figure 3).

Figure 3: Availability of equipment in 2018

Software. The questionnaire made the case that a majority of scientific organizations use widely out-of-date standard office programs of MS Office in most cases versions (1997-2003), (see Figure 4).

Such answers are quite consistent with answers to questions regarding equipment wear and tear level since computer equipment and their software are changing rapidly. The negative implications such situations have are, first, a large amount of memory, which is necessary when using outdated software, while new versions of programs

create similar documents, requiring less storage space. Second, a much wider range of tools, advanced features for data management, and analysis and visualization of data, teamwork is needed. Third, reflects the lack of efforts of scientific organizations to develop, renovate, and expand the digital skills of scientific workers, which is supported by respondents' responses in the following blocks of questions.

The Study of Software Usage Areas is of Interest (see Figure 5).

Figure 4: The Quality and Novelty of Office Software Programs

Figure 5: Software Usage Goals, number of programs

Scientific organizations more often use scientific software for research for the solution of organizational tasks and electronic document flow, but rarely for data bank access and education purposes. This leads to a situation in which scientific organizations generate knowledge and information, but do not pay enough attention to information management, classification, storage, accumulation, and access. These complexities carry the risk of losing part of the knowledge gained and fragmentation of knowledge. This stand finds endorsement in the following group of answers, regarding the IT specialists' availability and IT management in scientific organizations.

Personnel and digital skills. It should be noted that there is a high proportion of specialists with general digital skills (using standard office programs, the Internet) in scientific organizations. The answer to this question precludes from revealing the level of proficiency - elementary, experienced, advanced user. The situation changes essentially in the context of special digital skills (possession of special professional programs skills for analysis, modeling, and so on.). In a small number of respondents' answers, the share of such specialists reaches 50%.

Digital skills expansion in a negligible quantity can not be limited in formal education (training, courses, and so on.). On the whole, they are focused on obtaining general or most popular tasks. However, this knowledge requires further customization to the specific objectives of the activity or organization.

In our opinion, limited digital skills can reflect another issue - insufficient knowledge, overflow within the staff. A vast amount of knowledge is spread in the process of informal channels collaboration, knowledge sharing, and industrial training. The effects of knowledge overflow are widely described in the scientific literature. Therefore, scientific organizations must have the highest concern for issues related to the scientist's digital skills expansion, by using the skills of advanced specialists.

A primary consideration in the field of science digitalization is the training of specialists for work in the digital environment. Notwithstanding, the activity of scientific organizations is to improve the digital qualification of researchers (see Figure 5). Only 40% of organizations in the last 5 years have provided efforts to develop digital competence. In most cases from 1% to 5% of employees were covered by this activity, which is extremely insufficient, given the rate of expansion of the impact of digitalization.

The possibility to attract personnel who will be working in developing the digital environment has high importance in the evaluation of the digitalization of science. Accordingly, the potential of scientific organizations is to attract young scientists. In the organizations surveyed, the number of young scientists (under 35) were 1,083 people, or on average made up 32% of the number of organizations. The highest

proportion of young scientists in scientific organizations is in the field of natural sciences (biology, biotechnology) and medicine (35-48%), as well as scientific organizations related to the problems of development of mining and metallurgy (35-37%). The lowest proportion of young scientists is in the field of agriculture and space exploration (10-15%).

Consumers. Science in Kazakhstan develops under complex conditions. One of the main tasks of the current and the future period is to increase the authority and recognition of scientific organizations, the quality of scientific research, and the formation of demand for scientific products. To achieve this, various communication channels and corresponding information content should be formed in science. These questions are reflected in the section of the "Consumers" questionnaire (see Table 2).

Table 2: Consumers Engagement Level

No.	Research Institute	Availability of periodical electronic editions in open access	Availability of other electronic publications in the public domain	Availability of websites
		Unit	Unit	Yes/No
1	IMMS	0	2	Yes
2	NC CPMRM RK	0	1	Yes
3	IMA	0	0	No
4	Institute of Ionosphere	0	1	Yes
5	FAI	0	0	Yes
6	NCSTT	0	0	Yes
7	IMBB	0	0	Yes
8	Institute of Plant Biology and Biotechnology	0	0	Yes
9	KazIOR	1	1	Yes
10	KazRIAPG	0	0	Yes
11	KazSRIAHFP	0	0	Yes
12	KazRIFA	0	0	Yes
13	SPCGM	0	3	Yes
14	Institute of Oriental Studies	0	0	Yes
15	Institute of Economics	1	0	Yes

Table 3: Digital Readiness Rating of Research Institutes

Research Institute	Equipment availability		Software		Personnel and digital skills		Consumers		Digital readiness index	
	score	rating	score	rating	score	rating	score	rating	score	rating
Kazakh Institute of Oncology and Radiology (KazIOR)	4.68	5	2.37	6	12.68	1	3.67	3	5.85	1
National Center of Space Technique and Technology (NCSTT)	5.97	1	3.11	3	10.36	2	2.00	7...14	5.36	2
Institute of Plant Biology and Biotechnology	4.08	9	2.10	8	10.19	3	2.00	7...14	4.59	3
National Centre on Complex Processing of Mineral Raw Materials of the Republic of Kazakhstan (NC CPMRM RK);	3.68	13	5.60	1	3.50	7	3.67	4	4.11	4
M.Aitkhozhin Institute of Molecular Biology and Biochemistry (IMBB)	5.23	2	2.51	5	3.78	6	2.00	7...14	3.38	5
Institute of Mechanics and Machines Science named after Dzholdasbekov U.A. (IMMS);	3.06	14	3.01	4	4.02	4	3.33	5	3.36	6
Institute of Economics	4.04	10	1.49	12	3.16	9	4.67	1	3.34	7
Institute of Ionosphere	5.16	3	3.24	2	1.99	15	2.67	6	3.26	8
Scientific and Production Center for Grain Management named after A.I. Baraev (SPCGM)	4.94	4	1.08	14	2.23	13	4.00	2	3.06	9
Institute of Oriental Studies named after R. Suleimenov	4.38	7	1.51	11	3.99	5	2.00	7...14	2.97	10
Kazakh Research Institute of Forestry and Agroforestry (KazRIFA)	4.42	6	1.00	15	3.34	8	2.00	7...14	2.69	11
Kazakh Scientific Research Institute of Animal Husbandry And Forage Production (KazSRIAHFP)	3.88	12	1.52	10	2.74	11	2.00	7...14	2.53	12
Fesenkov Astrophysical Institute (FAI)	4.38	8	1.19	13	2.46	12	2.00	7...14	2.51	13
Kazakh Research Institute of Agriculture and Plant Growing (KazRIAPG)	3.93	11	1.94	9	2.11	14	2.00	7...14	2.49	14
Institute of Mining Affairs named after Kunayev D.A. (IMA)	2.73	15	2.12	7	2.82	10	1.00	15	2.17	15

Almost all scientific organizations, except one, have websites. However, these resources do not reflect a sufficient situation regarding the development of different directions and potential in science in Kazakhstan. There is no content on the websites, which is focused on potential users such as journals with full-text articles, articles, books, libraries, information about development, reports, etc. Hence, society does not have sufficient information, which allows having a clear picture of science development, scientists' achievements, and contribution to social development. This breeds discussion and often negative evaluation of the level of domestic research and the role of science. Scientific organizations have a poor presentation on social networking sites. Regardless it should be remembered that for the development of these activities, significant human and financial capital is required.

In accordance with the chosen method, the following are the ratings of Kazakhstan's research institutes (see Table 3).

According to the above-given calculations, there is high digital readiness at KazIOR, NCSTT, and Institute of Plant Biology and Biotechnology, who make up the top three, and the lowest indicator is at - IMA. On the whole, it can be noted that in Kazakhstan there is an average level of the digital readiness of scientific research institutes. Whereas the level of the digital readiness of research institutes in the technical profile field is higher than that of research institutes of humanitarian and agricultural profiles.

5. Conclusions

Digital technologies are a key driver of economic development. Governments focus on promoting digital technologies as an essential element of Industry 4.0. This is especially very important after the COVID-19 outbreak. Based on this scientific assumption, the degree of participation of each country will determine the level of development of science. Therefore, it is very important for Kazakhstan, like any other country, to take advantage and be able to assess the level of development of science to ensure rapid economic growth. The definitions of "readiness and "innovation" were examined from two leading points of view: the organization's willingness to resist innovation, and the organization's willingness to implement or guarantee innovation (Klein & Kozłowski, 2000; Weiner, Amick & Lee, 2008). This study focuses on the latter, assessing the organization's readiness to innovate with the introduction of digital technologies. In this way, digital readiness is oriented as a predisposition and willingness to switch to digital technologies and adopt them, as well as a willingness to develop new innovative abilities, applying these technologies to lead a person, company, branch, and country to achieve their own goals sooner and with huge results. In contrast to these studies, the creators will try to

make it cumulative, so that the concept of digital readiness on a personal level can be applied in all sorts of contexts.

The main contribution of our definition and with this research is its focus on a qualitative assessment of science and technology level of development with the use of digital components, especially in such developing countries as Kazakhstan, Russia, Belarus, etc. The study has proposed the methodology for evaluating the level of the digital readiness of scientific research institutes. The methodological basis was IDI and NRI with their adaptation at the organization level. The Scientific Research Institute's Digital Readiness Index proposed is based on four criteria: equipment availability, software, human resources, digital skills, and consumers. In general, the analysis of the level of the digital readiness of science and its consumers in Kazakhstan has led to the following conclusions.

First, the lack of theoretical content on the digital readiness of science at the organizational level in Kazakhstan suggests that to this date there are currently no platforms for discussing the theoretical problems of the digital readiness of science and its consumers in the country. At the same time readiness theory provides a comprehensive theoretical framework for developing an assessment of organizational readiness for digital innovation. The readiness doctrine provides a framework for obtaining appropriate systems for organizational readiness of science for digital innovations. The development of digital technologies has an impact on all sectors of the economy, especially in science. Technologies provide an opportunity to create and distribute data, information, knowledge, ideas, develop and commercialize innovations. It also provides tools through which the concept of the digital economy can be implemented to fully integrate digital technologies, data management methods, and real economic processes at the level of states, industries, and firms. A high level of the digital readiness of science and its consumers will lead to a quick transition to a digital economy and predict significant changes in the economy. These transformations include reducing transaction costs, increasing the innovation activity of individual enterprises and organizations in these industries, and creating and applying modern business models.

Second, the drawback of existing indices for assessing the development of digital technologies is that they are designed for usage within the framework of cross-country analysis. While digital technologies occupy a central place in updating key areas of the economy and its activities, they are a catalyst for innovative processes in individual industries. However, inter-industry analysis of digital development is not widespread. The authors proposed a methodology for assessing the level of the digital readiness of science using the digital readiness index of the research institute, calculated based on 4 criteria: equipment availability, software, personnel, and digital skills, consumers. Its methodological base was provided by IDI and NRI with

their adaptation at the organization level. A different feature of the authors' methodological tool is the analysis of the level of technological development and digital readiness of scientific–research institutes.

Third, in Kazakhstan, there is an average digital readiness of research institutes. At the same time, the level of the digital readiness of research institutes of a technical profile is higher than that of a research institute of humanitarian and agricultural profiles. Most of the Kazakhstani scientific organizations surveyed have a fairly high number of personal computers and the Internet. Scientific organizations more often use software for scientific research, for solving organizational problems, and electronic document management, but rarely for accessing databases and for training. At the same time, most research institutes widely use outdated versions of standard office programs. The proportion of professionals with general digital skills is high, while 50% of employees have specialized digital skills. The activities of scientific organizations to improve the digital qualifications of researchers are very passive. Of all respondents, almost all scientific organizations, except one, have websites, which have a poor presentation. One of the priority tasks in the current and the future period is to increase the authority and recognition of scientific organizations, the quality of scientific research, the formation of demand for scientific products, which requires improvement of the level of their digital readiness.

This study is a pioneer in assessing the level of technological development and digital readiness of scientific–research institutes in Kazakhstan. The scientific significance of this study lies in the fact that the ideas put forward in this scientific study– the theoretical and methodological principles developed in it, can significantly enrich the theory and practice of identifying the digital readiness of science and its consumers on the organizational level. The scientific results obtained during the study fill the gap of methodological and statistical basis for quality monitoring, analysis, evaluation, and forecasting of the digital readiness of the science and its consumers in Kazakhstan. Therefore, the research results show bottlenecks in the technological development and digital transformation of research institutes in Kazakhstan, which should be taken into account to determine the status and priority directions of its development. These tasks can become the next stage of the research.

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