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COMPOSITE DEVELOPMENT INDEX (CDI) AS A TOOL FOR HUMAN CAPITAL ASSESSMENT

Abstract. In the context of digitalization of national economies and the growing dependence of countries' competitiveness on the quality of human capital, it is necessary to move from classical assessment models (such as HDI) to more flexible and structurally adapted approaches. In this article, we have developed and tested an integrated model for assessing human capital, the Composite Development Index (CDI), which combines traditional socio-economic indicators with digital transformation metrics (DTI) and sustainable development (SDI). The CDI model is adapted to the socio-economic realities of Kazakhstan and takes into account regional specifics. As part of the empirical analysis, CDI calculations were made for 20 regions of the Republic of Kazakhstan. The data obtained demonstrate significant territorial heterogeneity in digital maturity and sustainable development of human capital. Comparison with HDI showed that CDI is more sensitive to digital inequality factors, the level of ICT infrastructure and the degree of integration of ESG components. Based on the analysis, measures are proposed to eliminate digital and environmental gaps: the creation of regional digital training centers, the development of EdTech platforms, and the introduction of a system of digital competency profiles. The use of CDI in combination provides a multi-level system for assessing and managing human capital that can be applied both in public policy and in the business environment of Kazakhstan.
Keywords: human capital; digital economy; Composite Development Index; Human Development Index.

INTRODUCTION

The socio-economic development of the Republic of Kazakhstan is characterized by a large-scale digital transformation covering all key sectors. Digitalization has become not only a priority of state policy, but also a factor changing the structure of the economy, the labor market and the system of requirements for human capital. In the context of digitalization, a new paradigm of value is being formed, in which human capital based on knowledge, skills and digital competencies plays a leading role.

The implementation of the state program «Digital Kazakhstan» and the «Concept of digital transformation, development of the information and communication technology industry and cybersecurity for 2023-2029» reflect the strategic desire to form a digital society. One of the central areas of these documents is the development of digital literacy and 21st century skills, including critical thinking, the ability to work with data, digital creativity and interdisciplinary communication.

It should be noted that Kazakhstan is demonstrating progress in global digital rankings. In 2024, the country ranked 24th out of 193 in EGDI, and also entered the top 10 in OSI, which indicates a high level of digital infrastructure and availability of public services. The planned transition to the eGov 3.0 model using artificial intelligence and big data processing technologies, as well as the export of IT services to more than 80 countries, confirm the international competitiveness of the IT sector of Kazakhstan. In the context of digitalization, the question arises of assessing the quality of human capital not only through the prism of basic socio-economic indicators, as in the HDI (Human Development Index) model, but also taking into account new factors of digital maturity and sustainable development. Although HDI remains an important indicator of living standards, it does not reflect critical parameters such as digital participation, technological literacy and the ability to innovate. In international practice, there is a growing interest in composite indices such as IMD (WDCI), DESI, but in the Kazakhstani context there is no single model that would integrate these aspects in assessing human capital. In this regard, there is an increasing need to develop adapted methods that allow for an objective assessment of the state and potential of human capital in the context of digitalization, which is especially important for the formation of effective state and regional policies in the field of employment, education and sustainable growth.

LITERATURE REVIEW

Many research scientists have analyzed various aspects of the impact of the digital economy on human capital. Thus, Grigorescu et al. examined the relationship between digitalization, ICT investments and welfare in Central and Eastern Europe. Using the example of 11 EU countries, they found a significant positive relationship between the level of digitalization, human capital and economic well-being of the population [1]. This empirical analysis shows that digital infrastructure enhances the contribution of human capital to socio-economic development. They also examined the impact of the digital economy on human capital and sustainability in Chinese cities in their works, showing the existence of a threshold HDI level necessary for the effective use of digital initiatives. This approach can be adapted to the Kazakhstani context. Yeraliyeva, Dauliyeva et al. [2] in the article «Effectiveness of public administration of the digital economy in Kazakhstan» identified the impact of digital policy on human capital, infrastructure and the regulatory environment. The authors emphasize the importance of public administration for the formation of digital competencies of the population and their economic impact.

In their works, Flores et al. [3] developed a comprehensive framework model of Human Capital 4.0, in which digital skills are identified as a core competency for adaptation to modern labor market challenges. Putri R. [4] proposed a formalized approach to the integration of digital competence, innovative capacity, and human capital management strategies to ensure the competitiveness of organizations in the digital era. But, in our opinion, he did not sufficiently take into account the level of human capital at the national level and specific digital indicators.

Khachaturyan A.A. in his works pointed out that automation can lead to the disappearance of a number of professions, changes in cognitive abilities, and the complexity of personnel adaptation [5].

Sembekov A., Tazhbaev N. et al. in their studies studied the role of digital modernization of the economy within the framework of global trends, stating the need to adapt human capital to new digital requirements [6]. Most of the models reviewed focus on infrastructure and ICT, often ignoring the intangible aspects of HC (digital competencies, soft skills and sustainability). In this regard, there is a need to develop an integrated CDI model that takes into account HDI, DTI and SDI, adapted to the Kazakhstani context.

MATERIALS AND RESEARCH METHODS

In our opinion, assessing human capital in the context of digitalization requires a transition from traditional indicators to expanded models that take into account both socio-economic and digital indicators. This study is based on a comprehensive methodological approach that

combines the principles of index modeling, data normalization and aggregation. Both classical and modern indices are used as a methodological base: HDI, a three-component indicator calculated by UNDP that assesses health, education level and per capita income; IHDI taking into account intra-country social differences; World Digital Competitiveness Index (WDCI) from IMD, which reflects digital competitiveness through measurements of knowledge, technology and readiness for future transformations; ICT Development Index (IDI) from ITU, which assesses access to digital infrastructure, skills and use of ICT; Digital Economy and Society Index (DESI), used in the EU to analyze digital progress and Global Connectivity Index (GCI), which assesses the level of connectivity and digital penetration in a global context. Despite the developed system of indices, there is a lack of a model integrating HDI and digital components in one indicator. In this regard, we propose a new model, the Composite Development Index (CDI).

The following will be used to build the model: official statistics, global and regional UNDP reports (HDI/IHDI), IMD reports on digital competitiveness, ITU data (IDI, ICT Skills), sustainable development indices (SDG Index) and our own calculations.

The study uses normalization methods, weighted aggregation and composite indexing. The Composite Development Index is calculated using the formula:

$$CDI=\omega_1 \cdot HDI+\omega_2 \cdot DTI+\omega_3 \cdot SDI$$

Where:

HDI – Human Development Index (UNDP),

DTI – Digital Transformation Index (according to the DESI/IMD model),

SDI – Sustainable Development Index (based on the SDG Index),

ω_1, ω_2, ω_3 (0.4; 0.3; 0.3) – weights reflecting priorities in the digital and sustainable growth strategy.

THE MAIN PART

For a reasonable construction of the composite CDI index, we will calculate the values of the HDI, DTI and SDI indices based on open data using UN formulas and adapted methods of international organizations.

HDI is calculated according to the UNDP methodology as the geometric mean of three normalized indicators:

$$HDI=(I_{LE} \cdot I_{Edu} \cdot I_{GNI})^{1/3}$$

Where:

I_{LE} – life expectancy index

I_{Edu} – education index

I_{GNI} – gross national income per capita index (PPP).

Table 1. Data for HDI calculation

Component	Indicator
Life expectancy	74,4 лет
Mean years of schooling	12,5 лет
GNI per capita (PPP, $)	$11 000

Source: [7]

In order to ensure comparability with international sources, the official HDI value of Kazakhstan for 2023, published in the Human Development Report (UNDP, 2024), is used in the calculations: HDI (Kazakhstan, 2023) = 0.837.

The DTI methodology is based on the DESI model from the European Commission and the IMD World Digital Competitiveness Ranking. In both models, the key domains are: Connectivity, Digital Public Services, Human Capital (Table 2).

Table 2. Digitalization Indicators (DTI)

Indicator	Value	Weight, %	Source / justification
Internet access level	0.79	30	Bureau of National statistics Agency for Strategic planning and reforms of the Republic of Kazakhstan, 2023 (share of households with internet access, 79%)
Digital government services	0.84	30	Ministry of Digital Development, Innovations and Aerospace Industry of the Republic of Kazakhstan, 2023 (share of users actively using eGov)
Digital competencies index	0.56	40	Adaptation of DESI and IMD World Digital Competitiveness Ranking, 2023 (based on the results of tests of digital literacy, digital interaction and use of ICT resources in the education system)

Source: [8-10]

$$DTI=0.3•0.79+0.3•0.84+0.4•0.56=0.237+0.252+0.224=0.713$$

The index was then normalized to a scale from 0 to 1, taking into account the distribution of countries according to IMD (Kazakhstan – 35th place out of 63, ~44th percentile) taking into account the median and calibration for Central Asian countries:

$$DTI_{norm} = \frac{35_{max} - 35}{63 - 1} = \frac{28}{62} = 0.451$$

(in reverse order)

The final value takes into account both methods:

$$DTI_{final} = \frac{0.713 + 0.451}{2} \approx 0.65$$

The calculation method of the sustainable development index SDI is based on the SDG Index from SDSN + environmental and social components, focusing on the works [18] and the SDG Country Performance rating (SDSN, Columbia University). The environmental block consists of: emissions, share of renewable energy sources, green education, 40% weight is given to education, as a more significant component within human capital (Table 3).

Table 3. Sustainable Development Indicators (SDI)

Indicator	Value	Weight, %	Source / justification
CO_2 emissions per capita	0.49	30	IEA (International Energy Agency), 2023 (emissions per capita ~11.5 t/person (average level)
Share of renewable energy sources in the energy balance	0.39	30	Ministry of Energy of the Republic of Kazakhstan, 2023 (share of renewable energy sources in the energy balance of Kazakhstan ~15%)
Access to environmental education	0.86	40	Forecast value according to the Ministry of Education of the Republic of Kazakhstan + UNESCO GCE Database (coverage level in school and university programs)

Source: [11-13]

$$SDI=0.3•0.49+0.3•0.39+0.4•0.86=0.147+0.117+0.344=0.608$$

The final index SDI_{final}=0.58 was calibrated to the scale of Central Asian countries to ensure comparability of the integral models.

Since the value of 0.608 is the original index calculated based on SDG/ESG data. The value of 0.58 is a normalized value used in the aggregate formulas, taking into account: the regional

level (Central Asia is lower in SDG than OECD countries), the alignment of the scale by regional percentile and the allowable interregional calibration for the comparability of the CDI.

These indicators were then aggregated by weights in the CDI formula to obtain a comprehensive index of sustainable digital human capital development in Kazakhstan. The final CDI for Kazakhstan was:

$$CDI= 0.4•0.837+0.3•0.65+0.3•0.58=0.7038$$

DTI and SDI in this study are based on international methodology, but were adapted to Kazakhstan. Similar composite approaches are actively used in strategic planning (for example, in the OECD, UNDP, EU), but this approach is unique in that it combines digital transformation and sustainable development in the context of assessing human capital (Table 4). The novelty of the study lies in the adaptation of the DESI and IMD digital indices to the conditions of Kazakhstan, the introduction of ESG components (environmental sustainability, «green» education) into the SDI model, and the construction of an integral CDI index for assessing human capital in the digital environment.

Table 4. Elements of novelty of the methodology for assessing human capital

Element	Characteristic	Explanation
Using HDI	Generally accepted methodology	Applied by UNDP, widely used
Adapting DTI with DESI/ IMD Components	Partially new adaptation	Novelty in the combination of indicators and weights adapted to the RK
Calculating SDI with an Ecological Focus	Methodological novelty	Proposed to strengthen the «E» in ESG in the human capital development model
Aggregation in CDI	Scientific novelty	Proposed a new composition of indices, justification of weights and transition from HDI to CDI

For the Republic of Kazakhstan, an integrated application of CDI indices is possible, since CDI helps to determine how prepared the country is for the digital economy at the macroeconomic level.

The results of the analysis of Kazakhstan's CDI in Table 5 demonstrate a certain regional differentiation in the level of human capital development.

Table 5. Comparative analysis of CDI by regions of the Republic of Kazakhstan

Region	CDI	HDI (official/rating)
Republic of Kazakhstan	0.7038	0.837
Almaty	0.765	0,85
Astana	0.749	0,842
Karaganda region	0.625	0,8
Atyrau region	0.621	0,795
Pavlodar region	0.618	0,79
East Kazakhstan region	0.612	0,79
Aktobe region	0.602	0,779
Mangistau region	0.600	0,778
Kostanay region	0.590	0,774
Akmola region	0.585	0,77
Kyzylorda region	0.580	0,768
Almaty region	0.579	0,765
West Kazakhstan region	0.570	0,765
Turkestan region	0.570	0,765
Zhambyl region	0.567	0,764

Region	CDI	HDI (official/rating)
North Kazakhstan region	0.565	0,762
Abay region	0.561	0,768
Ulytau region	0.560	0,76
Zhetysu region	0.553	0,762

Note: calculated by the authors

Analyzing the results of Table 5, we note that the leaders in digital transformation are the cities of Almaty (CDI 0.765) and Astana (CDI 0.749), which reflects a high degree of digitalization, the presence of a developed ICT infrastructure, and wide coverage of digital government services and educational platforms. High CDI values are also typical for industrial regions with active investments in technology and human capital (Karaganda (0.625), Atyrau (0.621) and Pavlodar (0.618). Regions with an average CDI level include East Kazakhstan region, Akmola, Mangistau, Kostanay regions (0.58–0.61). Some regions (Kyzylorda, Zhambyl) maintain moderate indicators, but need support for rural areas and personnel renewal. Outsiders in the CDI index are Zhetysu (0.553), Ulytau (0.560), Turkestan (0.570) and North Kazakhstan (0.565) regions. These regions lag behind in access to the Internet, weak digital inclusion and environmental adaptation of educational programs. In a number of regions (for example, Abay, Zhetysu, In the Ulytau region, there is a fairly high HDI, but a low CDI. This indicates a good basic social infrastructure (for example, education and healthcare), but a low level of digitalization and sustainable practices.

In large cities (Almaty, Astana), the CDI even exceeds the proportional HDI value, which is explained by the high density of ICT infrastructure, digital government services, an active digital economy and a startup environment.

Based on this, to increase the CDI level in the regions of Kazakhstan, we offer the following recommendations: for regions with a low CDI (<0.57), develop regional digital literacy programs based on colleges and universities as part of the implementation of the Education Development Program for 2023-2027, integrate ESG components into school and vocational education. For regions with an average CDI (0.57-0.62), it is necessary to create “digital competence maps of the population” at the level of public service centers (Figure 1) and integrate them into regional labor exchanges. Introduce digital dashboards and SDG/ESG monitoring at the level of regional akimats to assess educational and personnel sustainability.

Highly developed regions of Kazakhstan can export digital educational platforms and e-learning solutions (for example, Coursera.kz, OpenU.kz) to other regions through subsidies and franchising; monitor CDI in real time with reference to demography, migration, employment, in every possible way support outsider regions to develop digital strategies.

CONCLUSION

The article presents the methodology for assessing human capital Composite Development Index (CDI), which integrates traditional socio-economic indicators (HDI) with digital and environmental metrics (DTI and SDI). CDI calculations for the regions of Kazakhstan showed territorial differentiation: high values in megacities (Almaty, Astana), average in industrial centers (Karaganda, Pavlodar) and low in agrarian-subsidized regions (Zhetysu, Abay, Ulytau regions). A comparative analysis of the CDI and HDI demonstrated that the CDI is more sensitive to the modern challenges of digital inequality.

The CDI methodology can be used as a tool for regional strategic planning, assessing digital skills deficits, and developing educational and labor policies.

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COMPOSITE DEVELOPMENT INDEX (CDI) КАК ИНСТРУМЕНТ ОЦЕНКИ ЧЕЛОВЕЧЕСКОГО КАПИТАЛА

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Аннотация. В условиях цифровизации национальных экономик и растущей зависимости конкурентоспособности стран от качества человеческого капитала, становится необходимым переход от классических моделей оценки (таких как HDI) к более гибким и структурно адаптированным подходам. В настоящей статье разработана и апробирована интегральная модель оценки человеческого капитала Composite Development Index (CDI), объединяющая традиционные социально-экономические индикаторы с метриками цифровой трансформации (DTI) и устойчивого развития (SDI). Модель CDI адаптирована к социально-экономическим реалиям Казахстана и учитывает региональную специфику. В рамках эмпирического анализа произведены расчеты CDI по 20 регионам Республики Казахстан. Полученные данные демонстрируют значительную территориальную неоднородность цифровой зрелости и устойчивого развития человеческого капитала. Сравнение с HDI показало, что CDI более чувствителен к факторам цифрового неравенства, уровню ИКТ-инфраструктуры и степени интеграции ESG-компонентов. На основе анализа предложены меры по устранению цифровых и экологических разрывов: создание региональных центров цифровой подготовки, развитие EdTech-платформ, внедрение системы цифровых профилей компетенций. Использование CDI в совокупности предоставляет многоуровневую систему оценки и управления человеческим капиталом, которая может применяться как в государственной политике, так и в бизнес-среде Казахстана.
Ключевые слова: человеческий капитал; цифровая экономика; Composite Development Index; Human Development Index.

АДАМИ КАПИТАЛДЫ БАҒАЛАУДЫҢ ҚҰРАЛЫ РЕТІНДЕГІ COMPOSITE DEVELOPMENT INDEX (CDI)

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Аңдатпа. Цифрландырылған ұлттық экономикалар жағдайында және елдердің бәсекеге қабілеттілігі адами капиталдың сапасына тәуелділігі артқан сайын, дәстүрлі бағалау модельдерінен (мысалы, HDI) неғұрлым икемді әрі құрылымдық бейімделген тәсілдерге көшу қажеттілігі туындайды. Осы мақалада дәстүрлі әлеуметтік-экономикалық индикаторларды, цифрлық трансформация метрикаларын (DTI) және тұрақты даму көрсеткіштерін (SDI) біріктіретін адами капиталды бағалаудың интегралды моделі – Composite Development Index (CDI) әзірленіп, сынақтан өткізілді. CDI моделі Қазақстанның әлеуметтік-экономикалық ерекшеліктеріне бейімделіп, өңірлік спецификаны ескереді. Эмпирикалық талдау аясында Қазақстан Республикасының 20 өңірі бойынша CDI есептеулері жүргізілді. Алынған деректер адами капиталдың цифрлық жетілуі мен тұрақты дамуы тұрғысынан елеулі аумақтық теңсіздікті көрсетеді. HDI-мен салыстырғанда, CDI цифрлық теңсіздік факторларына, АКТ инфрақұрылымының деңгейіне және ESG-компоненттерінің интеграция дәрежесіне неғұрлым сезімтал екені анықталды. Талдау нәтижесінде цифрлық және экологиялық алшақтықты жоюға бағытталған бірқатар шара ұсынылды: өңірлік цифрлық даярлық орталықтарын құру, EdTech-платформаларды дамыту, біліктіліктердің цифрлық профильдері жүйесін енгізу. CDI моделін қолдану адами капиталды бағалау мен басқарудың көпдеңгейлі жүйесін ұсынады, ол Қазақстандағы мемлекеттік саясатта да, бизнес ортада да пайдалануға қолайлы.

Түйін сөздер: адами капитал; цифрлық экономика; Composite Development Index; Human Development Index.