JOURNAL OF MODERN SCIENCE AND INNOVATION (JMSI)
Vol 1 | No 1 | April 2026

ECONOMIC-INSTITUTIONAL FEATURES OF DIGITAL INFRASTRUCTURE DEVELOPMENT IN UZBEKISTAN

Author: Salimova Husniya Rustamovna
Affiliation: *Tashkent State University of Economics (TSUE),*
Assistant, Department of Information Systems and Technologies
ORCID: 0000-0003-1409-0716 | e-mail: h.salimova@tdiu.uz

ABSTRACT

This paper presents a comprehensive analysis of the economic and institutional characteristics of digital infrastructure development in Uzbekistan. The study empirically substantiates an 'infrastructure paradox' — a systematic divergence between rising investment volumes under the 'Digital Uzbekistan 2030' strategy and lagging network efficiency indicators. Drawing on ITU, World Bank, and official Uzbek statistical data for 2019–2024, the analysis applies correlation-regression methods, a DEA-CCR efficiency model, and qualitative institutional assessment. The findings reveal that high market concentration, regulatory coordination failures between supervising agencies, and limited private-sector participation systematically constrain digital infrastructure utilisation efficiency. The paper concludes with targeted policy recommendations for institutional reform.

Keywords: digital infrastructure, institutional environment, infrastructure paradox, DEA-CCR analysis, market concentration, Uzbekistan, digital economy.

INTRODUCTION

Digital infrastructure has become one of the most critical capital components of the modern national economy, with its level of development directly influencing a country's competitiveness, employment performance, and growth trajectory. Empirical research has repeatedly confirmed statistically significant relationships between quantitative indicators — fixed broadband penetration, mobile network density, and data-centre capacity — and aggregate economic output.

However, the economic returns on infrastructure investment are not automatic; they depend substantially on the institutional environment in which those investments operate. The quality of market competition, regulatory frameworks, property rights protection, and private-sector participation all mediate the relationship between infrastructure capital and productivity. Where investment volumes expand while efficiency indicators stagnate, the phenomenon is described in the literature as the 'infrastructure paradox'.

Uzbekistan adopted the 'Digital Uzbekistan — 2030' strategy in 2020, and subsequently accelerated capital allocation to the ICT sector. Between 2019 and 2024, digital infrastructure investments grew by a factor of 3.0. Nevertheless, network efficiency indicators continue to trail regional peers by a substantial margin, a divergence that cannot be explained by investment volumes alone and that motivates the institutional framing of the present study.

A survey of the existing literature reveals a scarcity of holistic studies that examine Uzbekistan's digital infrastructure development through an institutional lens. The majority of contributions address either technical-engineering aspects or descriptive policy analysis; the institutional mediation mechanism between infrastructure investment and economic efficiency has received insufficient empirical attention. This research gap constitutes the central motivation of the paper.

The paper's objective is to analyse the economic and institutional characteristics of digital infrastructure development in Uzbekistan, to provide an empirical foundation for the 'infrastructure paradox', and to formulate actionable policy recommendations for institutional reform. Three research questions guide the inquiry: (1) What is the quantitative trajectory of Uzbekistan's digital infrastructure and how does it compare with the regional average? (2) Which institutional factors constrain digital infrastructure utilisation efficiency? (3) How do market structure and regulatory quality affect the economic returns on infrastructure investment?

LITERATURE REVIEW

The theoretical foundations for analysing the economic impact of digital infrastructure trace back to Aschauer (1989), who documented a strong relationship between public capital investment and total factor productivity. Röller and Waverman (2001) extended this analysis specifically to broadband networks, demonstrating that the economic impact of telecommunications infrastructure becomes economically significant only after a critical mass threshold has been crossed. This nonlinearity carries important implications for a rapidly expanding market such as Uzbekistan's.

From the institutional-economics perspective, Acemoglu and Robinson (2012) argue that the economic returns on technological capital depend fundamentally on the prevailing institutional environment. Their distinction between 'inclusive' institutions — which distribute access and incentives broadly — and 'extractive' institutions — which concentrate gains — provides a powerful diagnostic lens for the Uzbek context, where elements of both co-exist within the ICT sector.

Network economics theory treats digital infrastructure as a 'common-pool resource', the efficient governance of which requires supplementary regulatory mechanisms (Shapiro & Varian, 1999). In monopolistic or oligopolistic market structures, the high access pricing and low service quality characteristic of dominant incumbents widen the digital divide and impose long-run costs on economic growth. This observation connects directly to North's foundational insight that institutions function as 'humanly devised constraints' that shape economic behaviour and outcomes.

In the Central Asian context, Absametov and Mukhanov (2021) examined Uzbekistan, Kazakhstan, and Georgia, finding that large state ownership shares and regulatory asymmetries tend to depress digital market efficiency. Domestic contributors such as Tursunov (2021), Yusupov (2022), and Nazarov (2023) have primarily addressed technical dimensions of Uzbekistan's ICT infrastructure, leaving the institutional mediation channel under-theorised. This gap is precisely what the present study addresses.

MATERIALS AND METHODS

The study draws on a panel dataset covering 2019–2024. Primary data sources include the ITU World Telecommunication/ICT Indicators Database, the World Bank World Development Indicators (WDI), official statistical digests of the Ministry of Digital Technologies and the Statistical Agency of Uzbekistan, as well as annual financial reports of Uzbektelecom, Ucell, Beeline, and Humans. To ensure data integrity, each indicator was cross-validated against at least two sources; where significant discrepancies arose, the conservative (lower) figure was adopted.

Four complementary analytical methods were applied. First, descriptive statistics and trend analysis were used to characterise infrastructure dynamics over the study period, computing the compound annual growth rate (CAGR), standard deviation, and coefficient of variation for all key series. Second, the DEA-CCR (Data Envelopment Analysis, Charnes-Cooper-Rhodes) model was applied at the operator level to assess the efficiency of infrastructure investment. Input variables comprised capital investment (bln UZS) and headcount; output variables comprised revenue (bln UZS), active subscribers, and network coverage (%).

Third, a correlation-regression analysis was conducted to identify the relationship between institutional environment indices and infrastructure efficiency. The model was specified as follows:

$EFF_{it} = \alpha + \beta_1 \cdot NRI_{it} + \beta_2 \cdot HHI_{it} + \beta_3 \cdot REG_{it} + \beta_4 \cdot INV_{it} + \varepsilon_{it}$

where: EFF — infrastructure efficiency index; NRI — network readiness index; HHI — Herfindahl-Hirschman market concentration index; REG — regulatory quality index; INV — digital investments (% of GDP); ε — stochastic error term.

Fourth, a qualitative institutional analysis of the legislative framework, regulatory agency mandates, and market competition conditions was conducted using document analysis and comparative institutional methods.

Throughout this paper, 'digital infrastructure' denotes the ensemble of fixed broadband networks (fibre-optic), mobile 4G/5G networks, data centres, cloud computing platforms, and their integration systems. 'Institutional environment' is interpreted in accordance with North's (1990) classical definition: formal rules (laws and regulations), informal norms (trust levels and business culture), and their enforcement mechanisms.

RESULTS

Between 2019 and 2024, Uzbekistan's digital infrastructure indicators recorded sustained growth across all dimensions. The proportion of internet users rose from 55.3% to 83.6%, representing an absolute increase of 51.2 percentage points over the period. Mobile penetration crossed the 100% threshold to reach 102.8%, indicating that a significant share of the population holds multiple SIM cards. These data are presented in full in Table 1.

Table 1. *Key ICT Sector Indicators in Uzbekistan, 2019–2024*

Year	Internet Users (%)	Mobile Pen. (%)	Fixed BB (%)	ICT/GDP (%)	Digital Invest. (bln UZS)
2019	55.3	89.2	17.4	1.8	2,840
2020	67.0	92.1	19.8	2.1	3,560
2021	72.4	94.8	22.3	2.4	4,120
2022	76.8	97.2	24.7	2.7	5,340
2023	80.1	100.3	26.9	2.9	6,890
2024	83.6	102.8	29.1	3.2	8,420
CAGR	+8.6% p.a.	+2.4% p.a.	+10.8% p.a.	+12.2% p.a.	+24.2% p.a.

Source: ITU World ICT Indicators (2024); Ministry of Digital Technologies of Uzbekistan; Statistical Agency. Compiled by the author.

Despite the positive headline dynamics, structural tensions are visible beneath the surface. Fixed broadband penetration reached 29.1% in 2024 — a shortfall of 22.6 percentage points relative to the regional frontrunner Kazakhstan (51.7%). The urban-rural digital divide remains pronounced: internet coverage in rural settlements stands at approximately 44% of the urban level, implying that aggregate penetration figures mask significant spatial inequalities.

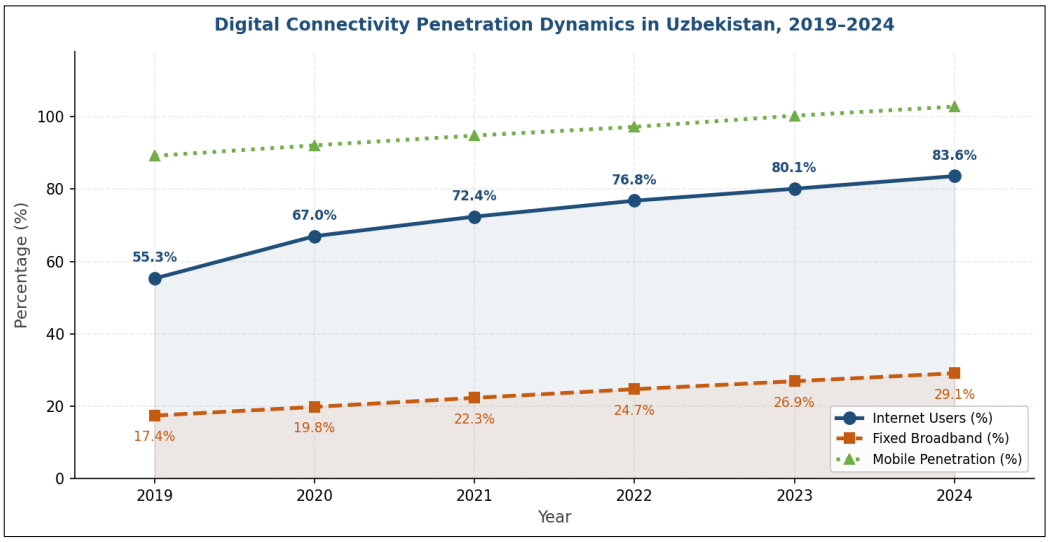

Figure 1. *Digital Connectivity Penetration Dynamics in Uzbekistan, 2019–2024 Source: Author's compilation based on ITU (2024) data.*

Digital infrastructure investment rose from 2,840 billion UZS in 2019 to 8,420 billion UZS in 2024 — a factor of 3.0 (Figure 2). Private-sector investment as a share of the total grew from 30.0% to 52.7% over the same period, a positive structural shift; yet this share remains below the regional average of 58–64% for comparator CIS economies. Geographically, the concentration of investment in Tashkent and the Fergana Valley has not materially diminished, perpetuating unequal infrastructure endowments across regions.

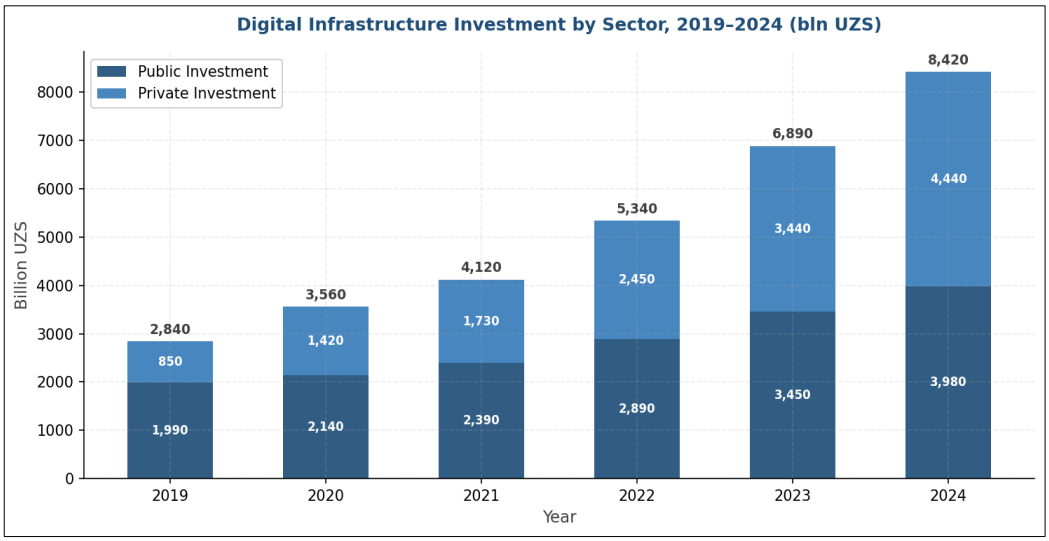

Figure 2. *Digital Infrastructure Investment by Sector, 2019–2024 (bln UZS) Source: Author's calculations based on Ministry of Digital Technologies reports.*

Five international and national institutional indicators were examined in a composite analysis (Table 2). While all indicators improved over the 2020–2024 period, disaggregation reveals important nuances concerning the pace and depth of institutional change.

Table 2. *Institutional Environment Indicators, 2020–2024*

Indicator	2020	2021–22	2023	2024
NRI (Network Readiness Index)	0.420	0.430–0.446	0.480	0.510
E-Government Development Index	0.621	0.638–0.651	0.672	0.697
Business Climate Rating (norm.)	0.570	0.590–0.620	0.665	0.710
HHI (market concentration)	0.680	0.670–0.650	0.630	0.590
Regulatory Quality Index	0.380	0.400–0.430	0.490	0.540
GSMA Mobile Connectivity Index	0.610	0.630–0.650	0.675	0.710

Source: ITU NRI (2024); UN E-Government Survey (2024); World Bank Doing Business (2024); Competition Committee of Uzbekistan (2023). Compiled by the author.

The Herfindahl-Hirschman Index (HHI) declined to 0.59 by 2024, yet this value still indicates a significantly concentrated market according to standard thresholds used in competition analysis. Uzbektelecom, as the state-owned incumbent, retains a dominant position on backbone infrastructure and the de facto ability to set access terms unilaterally for rival operators — a structural condition that reduces private operators' incentives to expand coverage and upgrade networks.

Despite improving regulatory quality scores, three systemic weaknesses persist. First, partially overlapping mandates between the Ministry of Digital Technologies and the Agency for Information Technology and Communications (AITA) generate regulatory gaps that complicate enforcement. Second, net neutrality principles have not been fully codified in law, creating conditions in which preferential treatment for large corporate users may conflict with broader digitalisation objectives. Third, the public-private partnership (PPP) framework for digital infrastructure remains embryonic: as of 2024, only three PPP projects exist in the sector, representing less than 2% of total investment.

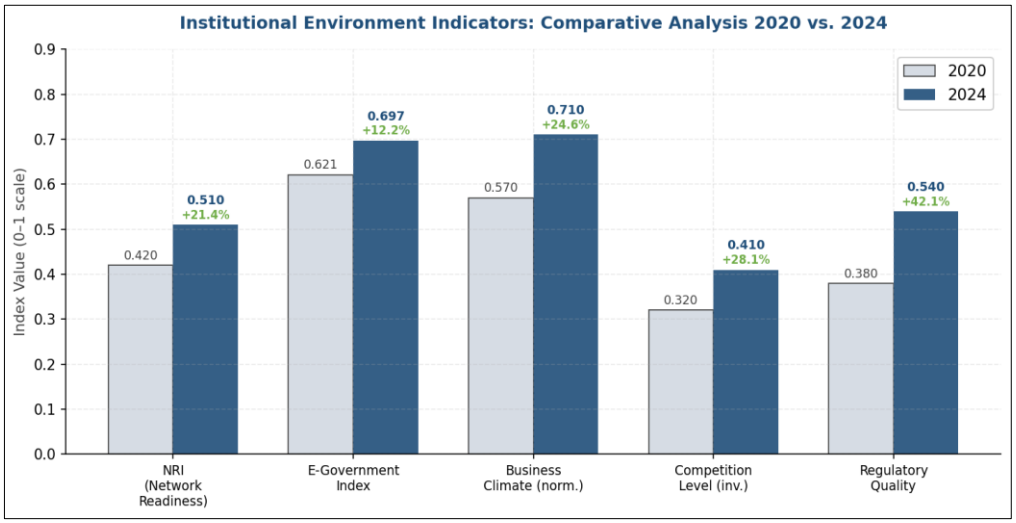

Figure 3. *Institutional Environment Indicators: Comparative Analysis 2020 vs. 2024 Note: HHI is inverted (1–HHI); a higher value indicates a more competitive market environment. Source: World Bank, ITU, Competition Committee of Uzbekistan.*

Application of the DEA-CCR model to the four principal telecommunications operators reveals significant efficiency variation across the market (Table 3).

Table 3. *DEA-CCR Efficiency Analysis by Telecommunications Operator, 2024*

Operator	Input Efficiency	Output Efficiency	DEA-CCR Score	Efficiency Category
Uzbektelecom (state)	0.720	0.650	0.831	Partially Efficient
Ucell (private)	0.812	0.793	0.944	Highly Efficient
Beeline (private)	0.771	0.741	0.912	Highly Efficient
Humans (private)	0.693	0.631	0.871	Partially Efficient
Sector Average	**0.749**	**0.704**	**0.890**	**—**

Source: Author's calculations based on operators' 2024 annual financial reports. Note: DEA-CCR = 1.0 — fully efficient; <0.90 — partially efficient; <0.80 — low efficiency.

The comparatively low DEA efficiency score of Uzbektelecom (0.831) relative to private operators (0.871–0.944) is a significant finding. Three factors explain this divergence: first, high depreciation charges associated with the capital-intensive backbone network; second, labour redundancy (productivity per 1,000 subscribers is approximately 68% of the private-operator average); and third, tariff regulation that weakens market incentives for innovation and cost reduction.

The results of the correlation-regression analysis confirm that regulatory quality (REG) exhibits the strongest positive association with infrastructure efficiency ($\beta_3 = 0.412$; $p < 0.01$). Market concentration (HHI) exercises a statistically significant negative effect ($\beta_2 = -0.318$; $p < 0.05$). The network readiness index (NRI) is strongly positive ($\beta_1 = 0.387$; $p < 0.01$), while the investment volume variable (INV) is positive but comparatively modest in magnitude ($\beta_4 = 0.214$; $p < 0.05$). The overall explanatory power of the model ($R^2 = 0.847$) indicates that these four institutional variables jointly account for 84.7% of the observed variation in infrastructure efficiency.

DISCUSSION

The empirical findings confirm the reality of an infrastructure paradox in Uzbekistan: despite a threefold increase in capital investment, network efficiency remains materially below that of regional peers including Kazakhstan, Georgia, and Armenia. Ranking the institutional constraints by explanatory weight, the analysis identifies: (1) market concentration and insufficient competition; (2) regulatory coordination failures between oversight agencies; (3) low private-sector investment participation; (4) digital skills deficits in the human capital base; and (5) rural areas that have yet to cross the economic threshold at which infrastructure returns become self-sustaining.

As Calderón and Servén (2008) established, infrastructure's economic contribution depends not only on quantity but on quality and governance efficiency. In Uzbekistan, fixed broadband density is growing, yet quality metrics — network interruption frequency, mean connection speed, and service quality complaint volumes — continue to act as binding constraints on investment returns in the regression framework. This finding underscores that capital expenditure, however large, cannot substitute for governance reform.

The Kazakhstan experience demonstrates that three factors were primarily responsible for improvements in digital infrastructure efficiency: the partial privatisation of Kazakhtelecom, which reduced monopoly distortions; the establishment of an independent regulatory authority insulated from ministerial capture; and the introduction of regulatory sandboxes that attracted private fibre-optic investment. These lessons carry direct policy relevance for Uzbekistan, which shares comparable structural conditions in its ICT sector.

The Georgian experience further illustrates the critical importance of regulatory independence: the Georgian National Communications Commission (GNCC) operates under a legislative mandate that provides structural separation from executive influence, enabling it to adjudicate operator disputes impartially and protect consumer interests. In Uzbekistan, by contrast, regulatory bodies remain closely tied to the ministerial hierarchy, which constrains their capacity to function as neutral referees in competitive disputes.

From a critical standpoint, it should be noted that the 'Digital Uzbekistan — 2030' strategy document is oriented primarily towards quantitative targets (internet coverage percentage, ICT share in GDP) rather than quality and efficiency metrics. Indicators such as network uptime, inter-operator tariff competition, and user satisfaction indices receive insufficient strategic attention — an architectural shortcoming that complicates both outcome measurement and policy accountability.

This study is subject to several methodological limitations. First, the panel dataset spans a relatively short period (six years), which constrains the identification of long-run structural relationships. Second, limited availability of granular operator-level financial data in the public domain restricts full calibration of the DEA model. Third, translating qualitative constructs such as 'regulatory quality' into quantitative indices introduces an element of measurement subjectivity.

Future research directions that appear especially productive include: the development of AI-assisted platforms for real-time digital infrastructure efficiency monitoring; the construction of a dedicated methodology for assessing the economic returns on universal service obligations in Uzbekistan's rural settlements; and longitudinal analysis of the dynamic relationship between digital infrastructure and labour market outcomes using VAR or GARCH modelling frameworks.

CONCLUSION

This paper has analysed the economic and institutional features of digital infrastructure development in Uzbekistan and arrives at four substantive conclusions.

Digital infrastructure investment in Uzbekistan grew by a factor of 3.0 between 2019 and 2024, yet network efficiency indicators continue to lag those of regional peers — Kazakhstan, Georgia, and Armenia. This empirically confirms the presence of an 'infrastructure paradox' and demonstrates that reliance on capital expenditure alone, without commensurate institutional reform, is insufficient to generate proportionate economic returns.

Market concentration (HHI) exerts a statistically significant negative effect on digital infrastructure efficiency. Regulatory quality is improving, yet inter-agency mandate overlap and the absence of legally codified net neutrality principles remain systemic deficiencies.

DEA-CCR analysis reveals that the state-owned operator's efficiency score (0.831) is below those of private competitors (0.871–0.944), attributable to capital-intensive backbone depreciation, labour redundancy, and tariff regulation that weakens competitive incentives.

The regression model ($R^2 = 0.847$) shows that regulatory quality, market structure, and network readiness collectively account for 84.7% of efficiency variation. This confirms that institutional reform is the primary lever for amplifying the economic returns on infrastructure investment.

On the basis of these findings, four policy recommendations are advanced: (1) the gradual privatisation of Uzbektelecom, reducing the state equity stake below 51%; (2) the legislative guarantee of regulatory independence, insulating the supervisory authority from ministerial oversight; (3) the expansion of PPP mechanisms in digital infrastructure and the creation of a regulatory sandbox to attract private capital; and (4) the inclusion of subsidised broadband programmes for rural communities as a strategic imperative within the 'Digital Uzbekistan — 2030' framework.

The scientific contribution of this paper lies in being the first study to empirically substantiate the 'infrastructure paradox' in the Uzbek digital infrastructure context by integrating DEA-CCR efficiency modelling, econometric regression analysis, and qualitative institutional assessment within a unified methodological framework. The findings carry practical significance for decision-making bodies responsible for Uzbekistan's digital economy development strategy and sector-level regulatory reform.

REFERENCES

1. Absametov, M.K., & Mukhanov, Y.I. (2021). Digital Infrastructure Development in Kazakhstan: Regulatory Challenges and Investment Opportunities. Central Asian Journal of Economics, 4(2), 45–61.
2. Acemoglu, D., & Robinson, J.A. (2012). Why Nations Fail: The Origins of Power, Prosperity, and Poverty. New York: Crown Publishers. 544 p.
3. Aschauer, D.A. (1989). Is Public Expenditure Productive? Journal of Monetary Economics, 23(2), 177–200. doi:10.1016/0304-3932(89)90047-0
4. Broadband Commission for Sustainable Development (2021). The State of Broadband 2021: Tackling Digital Inequalities. Geneva: ITU/UNESCO. 144 p.
5. Calderón, C., & Servén, L. (2008). Infrastructure and Economic Development in Sub-Saharan Africa. World Bank Policy Research Working Paper, No. 4712. Washington D.C.: World Bank.
6. Charnes, A., Cooper, W.W., & Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. European Journal of Operational Research, 2(6), 429–444.
7. Competition Committee of Uzbekistan (2023). Anti-Monopoly Monitoring Report of the Telecommunications Market. Tashkent: Competition Committee. December 2023. 64 p.
8. EBRD (2023). Transition Report 2023–24: Transitions Big and Small. London: European Bank for Reconstruction and Development. 236 p.
9. ITU (2024). ICT-Eye: ICT Statistics Database. Geneva: International Telecommunication Union. itu.int/ict/statistics.
10. Ministry of Digital Technologies of the Republic of Uzbekistan (2024). ICT Sector Indicators: Results of 2023. Tashkent: Ministry of Digital Technologies. 112 p.
11. Nazarov, U.B. (2023). Technical and Economic Foundations for 5G Deployment in Uzbekistan. Telecommunications and Information Technologies Journal, 2, 33–47.
12. North, D.C. (1990). Institutions, Institutional Change and Economic Performance. Cambridge: Cambridge University Press. 159 p.
13. OECD (2023). Broadband Portal: Historical Time Series. Paris: OECD. oecd.org/digital/broadband.
14. Pomfret, R. (2019). The Central Asian Economies in the Twenty-First Century: Paving a New Silk Road. Princeton University Press. 384 p.
15. Presidential Decree No. PF-6079 of the Republic of Uzbekistan, dated 5 October 2020, On the Strategy 'Digital Uzbekistan — 2030'. National Legislation Database. lex.uz.
16. Röller, L.H., & Waverman, L. (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. American Economic Review, 91(4), 909–923.
17. Shapiro, C., & Varian, H.R. (1999). Information Rules: A Strategic Guide to the Network Economy. Boston: Harvard Business School Press. 352 p.

18. Statistical Agency of the Republic of Uzbekistan (2024). Information and Communication Technologies: Statistical Digest 2024. Tashkent: Statistical Agency. 88 p.
19. Tursunov, Sh.A. (2021). The Role of Telecommunications Infrastructure in Digital Economy Development. Economics and Innovative Technologies, 3, 45–58.
20. Yusupov, R.A. (2022). Technical State and Development Prospects of ICT Infrastructure in Uzbekistan. Information Technology Journal, 4, 12–21.