

Digital Infrastructure and Regional Economic Development: Comprehensive Assessment of Digitalization in the Regions of Azerbaijan

Afat Mammadova⁰⁰⁰⁰⁻⁰⁰⁰²⁻⁷¹⁶⁹⁻³⁰⁸¹

Azerbaijan University of Architecture and Construction
Azerbaijan, Baku

afat.mammadova@azmiu.edu.az

Abstract. In Azerbaijan, digitalization has been identified as a strategic priority within the framework of national development programs aimed at economic diversification, innovation-based growth, and improved governance.

The article offers a comprehensive methodological framework that combines socio-economic indicators and spatial analysis to assess digital development in the regions of Azerbaijan, including large urban centers and the Karabakh Economic Region. The methodology includes indicators related to ICT infrastructure, digital accessibility, human capital and digital economic activity, which allows for a multidimensional comparison of regions, as well as an assessment of the level of regional digitalization in Azerbaijan and an examination of the role of digital infrastructure in promoting economic development and achieving sustainable results.

Baku, being the undisputed leader in the level of implementation and application of IT technologies, has become the main digital and technological center of the country, however, territorial asymmetries remain in the level of deployment of digital infrastructure, the maturity of the IT ecosystem and the integration of digital technologies into regional economic structures. At the same time, many non-metropolitan regions have significant infrastructural, industrial and sectoral potential, which can serve as a basis for sustainable development based on digital technologies. This issue has become particularly relevant in the post-conflict context of the Karabakh Economic Region, where large-scale reconstruction creates a unique opportunity to introduce digital and intelligent technologies from the very beginning. Thus, the region is an important analytical example for studying the role of digital infrastructure in sustainable regional development.

Empirical data reveal a pronounced regional asymmetry in the development of digital infrastructure, closely related to differences in economic indicators, investment attractiveness and innovation potential. The results highlight the strategic importance of targeted investments in digital infrastructure for balanced regional development and sustainable economic transformation. The study developed a consolidated regional digitalization Index (CRDI), which reflects digital infrastructure, accessibility, human capital, and digital economic activity in the regions of Azerbaijan, including the Karabakh Economic Region.

The results show significant regional differences in digital development, with leading urban regions demonstrating higher productivity, investment attractiveness, and economic diversification. At the same time, peripheral regions face risks of economic marginalization due to insufficient digital infrastructure and limited digital technology skills. The results show that digitalization acts as the most important factor of regional competitiveness, but requires additional investments in human capital and

institutional capacity. The study concludes that an inclusive and district-specific digital policy is essential to ensure balanced regional growth, economic sustainability, and long-term development of Azerbaijan.

Keywords: digital economy, regional development, digital infrastructure, sustainable development, Azerbaijan.

1. Introduction

The accelerating spread of digital technologies has fundamentally transformed economic systems, changing production processes, labor markets, and regional development trajectories. Digital infrastructure, including broadband, mobile networks, data centers, and digital government services, has become a key driver of economic competitiveness and long-term sustainable growth. In this context, digitalization is no longer seen solely as a technological phenomenon, but rather as a strategic foundation for regional economic development and spatial cohesion. Despite the global spread of digital technologies, significant regional differences remain in digital infrastructure and readiness for digital technologies, especially in developing countries and countries with economies in transition. These differences contribute to uneven economic growth, limited access to digital services, and reduced innovation potential in peripheral regions. The literature increasingly highlights that insufficient digital infrastructure can exacerbate existing socio-economic inequalities, while targeted investments in digital technologies can contribute to inclusive growth and regional convergence.

Azerbaijan provides a suitable example for studying the relationship between digital infrastructure and regional economic development. Over the past decade, the country has made significant efforts to modernize its information and communication technology (ICT) sector and integrate digital transformation into national development strategies. However, the level of digitalization in different regions remains uneven, with large urban centers demonstrating significantly higher digital technology readiness compared to peripheral and rural areas. These imbalances raise important questions about the effectiveness of current digital policies in promoting balanced regional development. This issue is of particular importance in the context of the Karabakh Economic Region, which is undergoing a large-scale post-conflict reconstruction and socio-economic revival. Digital infrastructure is increasingly seen as an essential component of sustainable recovery strategies, enabling the creation of smart cities, electronic public services, digital entrepreneurship, and effective resource management.

The integration of digital technologies into the Karabakh development model opens up opportunities not only for economic growth, but also for increasing institutional efficiency and social integration. Against this background, the purpose of this study is to assess the level of digitalization in the regions of Azerbaijan and to study the role of digital infrastructure in regional economic development from the point of view of sustainable development. The document proposes an integrated methodological framework that combines composite digitalization indexes with socio-economic indicators to assess regional differences and identify key drivers of digital-led growth.

By including both established regions and the Karabakh Economic Region in the analysis, the study aims to provide policy-relevant information for strategic regional planning and sustainable development. This study has three main aspects. First, it systematizes methodological approaches to measuring regional digitalization within a single analytical framework. Secondly, it provides an empirical assessment of the differences in digital infrastructure between the regions of Azerbaijan. Third, it highlights the strategic importance of digital infrastructure in post-conflict regional development, which contributes to the expansion of literature on the digital economy and sustainable regional growth.

2. Digital economy and regional economic growth

The concept of the digital economy has evolved from a narrow understanding of information and communication technologies (ICT) to a broader understanding encompassing digital platforms, data-driven business models, and government services using digital technologies. Numerous studies emphasize that digitalization acts as a catalyst for productivity growth, innovation, and structural transformation, especially at the regional level (Brynjolfsson & Hitt, 2000; Malecki, 2003). From the point of view of regional development, digital technologies reduce transaction costs, increase market accessibility and mitigate geographical restrictions. Empirical studies demonstrate a positive relationship between the spread of ICT and regional economic indicators, as measured by indicators such as gross domestic product, employment growth, and business density (Crescenzi & Rodriguez-Pose, 2012; Koutroumpis, 2009). Regions with developed digital infrastructure tend to attract more investment and demonstrate higher innovation potential. However, the literature also emphasizes that digitalization does not automatically lead to regional convergence. In many cases, the main digitally developed regions benefit disproportionately from technological progress, while peripheral regions lag behind, exacerbating spatial inequalities (Author, Dorn and Hanson, 2015). This dual effect highlights the importance of regional digital policy.

Digital infrastructure forms the fundamental layer of the digital economy, including broadband networks, mobile communications, cloud computing, and digital public infrastructure. Several studies have argued that digital infrastructure should be considered as a form of productive capital, comparable to transportation or energy infrastructure, due to its multiplicative impact on economic activity (Roller & Waverman, 2001). It has been shown that at the regional level, broadband penetration and mobile network coverage significantly affect firm productivity, labor market efficiency, and entrepreneurial activity (Forman, Goldfarb & Greenstein, 2012). Access to high-quality digital infrastructure allows firms to integrate into global value chains, adopt advanced manufacturing technologies, and use business models that require large amounts of data. Nevertheless, unequal access to digital infrastructure remains an ongoing problem. Rural and less developed regions often face lower investment incentives, leading to digital inequality that limits their economic potential (OECD, 2018). This issue is particularly relevant for emerging economies, where regional differences in infrastructure provision tend to be more pronounced.

In recent years, the relationship between digitalization and sustainable development has attracted more and more attention in academic and policy research. Digital technologies are widely recognized as driving the achievement of the Sustainable Development Goals (SDGs), contributing to economic growth (SDG 8), industry and innovation (SDG 9), and reducing inequality (SDG 10) (UNDP, 2020). From an environmental perspective, digital solutions contribute to more efficient use of resources through intelligent energy systems, intelligent transportation, and digital monitoring of environmental performance (Bieser & Hilty, 2018). Socially, digital public services and e-government platforms enhance institutional transparency and accessibility, improving governance outcomes. However, scientists warn that digitalization can also pose risks to sustainable development, including increased energy consumption, electronic waste, and digital isolation (UNEP, 2019). Thus, the net impact of digitalization on sustainability largely depends on the quality of governance, regulatory frameworks, and regional development strategies.

A wide range of methodological approaches has been developed to assess digitalization at the regional level. Composite indexes are one of the most frequently used tools combining a variety of indicators related to infrastructure, human capital, digital technology use and innovation (European Commission, 2022). Examples include the Digital Economy and Society Index (DESI) and various national digital readiness indexes. Despite their analytical usefulness, existing indexes often suffer from limitations such as data availability, insufficient regional detail, and limited applicability to developing or post-conflict regions. Some authors advocate context-dependent structures that take into account regional peculiarities and stages of development (Billon, Marco and Lera-Lopez, 2009). There is relatively little empirical research on regional digitalization in the context of Azerbaijan and countries with similar economies. Existing research mainly focuses on national-level indicators, which leaves a gap in understanding the differences in digital technologies within countries and their economic consequences. This gap is particularly evident in post-conflict regions, where digital infrastructure plays a strategic role in recovery and long-term sustainability.

The analyzed literature shows that although the relationship between digital infrastructure and regional economic development is well studied, empirical data on emerging market economies and countries emerging from conflict are limited. In addition, methodological approaches often fail to integrate digitalization indicators with regional sustainability-oriented analysis. This study addresses these gaps by offering a comprehensive methodological framework adapted to the regional context of Azerbaijan. By including the Karabakh Economic Region in the analysis, the article expands existing research in the field of digital economy and sustainable development, offering important policy ideas for balanced regional growth and digital transformation strategies.

3. Methodology

In this study, regional digitalization is considered as a multidimensional process reflecting the availability, accessibility and effective use of digital technologies in the regions of Azerbaijan. The framework is designed to cover not only the technical aspects of digital infrastructure, but also the socio-economic conditions that determine the ability of regions to benefit from digital transformation. Given the heterogeneity of the regions of Azerbaijan in terms of economic structure, population density and

development priorities, a regional analytical approach is applied. Special attention is paid to the Karabakh Economic Region, where the development of digital infrastructure is an integral part of post-conflict reconstruction and sustainable development strategies.

- The economic regions of Azerbaijan (including Baku, Absheron-Khizi, Gorno-Shirvan, Nakhichevan, Karabakh, East Zangezur, Ganja-Dashkesan, Shaki-Zagatala, Gazakh-Tovuz, Central Aran, Mil-Mugan, Lenkoran-Astara, Guba-Khachmaz and Shirvan-Salyan districts.) ;
- Major urban centers (Baku, Ganja, Sumgait);
- The Karabakh Economic Region as a separate analytical unit due to its strategic development status. This approach allows for both inter-regional comparisons and an assessment of digital inequality between cities and peripheries.

To assess the level of digitalization in the regions of Azerbaijan, the Consolidated Regional Digitalization Index (CRDI - Composite Regional Digitalization Index) was developed in order to assess the effectiveness of digital solutions in the public sector, identify development needs and plan measures to improve the situation. The index combines four key aspects reflecting the regional digital ecosystem.

Measurement	Indicators
Digital infrastructure	The level of broadband penetration into the digital infrastructure; mobile network coverage (4G/5G); number of Internet subscribers per 1,000 inhabitants
Accessibility and use of digital technologies	Proportion of households with Internet access in the digital environment; use of e-government services; use of digital payments
Human capital and skills	Percentage of the population with basic digital skills; employment in the field of ICT; number of students in ICT-related fields
Digital economic activity	Number of companies in the field of ICT; digital startups; share of ICT in regional value added

Table 1. Measurements and indicators of regional digitalization in Azerbaijan

The choice of indicators is based on the availability of data from national statistical sources and international criteria, which ensures consistency and comparability.

Each indicator is normalized using the min-max method to ensure comparability between regions. Equal weights are assigned to each dimension of the index, reflecting their balanced contribution to regional digital development.

The consolidated regional digitalization index is calculated as an arithmetic average of four dimensions.

This transparent weighing scheme allows you to reproduce the results and interpret them based on policy. Empirical analysis is based on data:

- The State Statistical Committee of the Republic of Azerbaijan;
- Ministry of Digital Development and Transport;
- International Telecommunication Union (ITU);
- World Bank and UNDP databases;
- Official reports on regional development.

Data problems, especially in recently reconstructed areas such as Karabakh, are solved using indirect indicators and qualitative assessment.

The study uses:

- Descriptive statistical analysis to assess the regional level of digitalization;
- Comparative analysis by region and urban centers;
- Correlation analysis to study the relationship between digitalization and regional economic performance indicators (GRP, employment, investment);
- Qualitative assessment for post-conflict regions where quantitative data remains limited.

The proposed methodology complements the literature by offering a context-sensitive framework for assessing regional digitalization in Azerbaijan. It combines digital infrastructure analysis with sustainable regional development goals and provides a practical tool for policy assessment and strategic planning.

4. Empirical analysis: Digitalization of Azerbaijan's regions

The regions of Azerbaijan differ significantly in terms of economic structure, population density and development potential, which directly affects the pace and results of digital transformation. Major urban centers, especially Baku and the Absheron Economic Region, are home to major economic activity, investment flows, and ICT infrastructure. In contrast, peripheral and rural regions show a lower level of economic diversification and infrastructure provision.

These structural differences create an uneven starting point for digitalization, reinforcing the importance of regionally differentiated digital development strategies. In this context, digital infrastructure serves as both a growth driver and a tool to mitigate spatial inequalities.

The calculated Consolidated Regional Digitalization Index (CRDI) shows clear differences between the regions of Azerbaijan. Baku and the Absheron region show the highest index values, due to the high level of broadband penetration, extensive mobile network coverage, high usage of digital services and a high concentration of ICT companies.

Regions such as Ganja-Dashkesan and Sheki-Zagatala occupy intermediate positions, reflecting the moderate development of digital infrastructure and growing digital human capital. These regions benefit from regional urban centers and educational institutions that support the formation of digital skills.

Conversely, in regions such as Mountain - Shirvan, Central Aran, and parts of the southern and northern periphery, the level of digitalization is lower. Limited broadband access, low digital technology proficiency, and declining digital economic activity limit their ability to take full advantage of digital transformation opportunities.

In Azerbaijan, there is a clear digital divide between cities and the periphery. Urban centers demonstrate a significantly higher level of density of digital infrastructure and

the use of digital services compared to the surrounding rural areas. This gap is evident not only in physical connectivity, but also in digital competencies and economic outcomes.

The persistence of this gap indicates that a digitalization policy focused solely on national averages may not take into account critical intraregional differences. Thus, targeted measures at the sub-regional level are necessary to ensure comprehensive digital development.

The Karabakh Economic Region is a unique case in the digital landscape of Azerbaijan. As part of post-conflict reconstruction, the development of digital infrastructure has been integrated into the broader Smart City and Smart Village initiatives. Investments in high-speed communications, digital public services, and intelligent infrastructure systems are aimed at supporting effective governance and sustainable economic activity.

Although comprehensive quantitative data is still limited, a qualitative assessment shows that digital infrastructure is positioned as a fundamental element of the Karabakh development model. The region's digitalization strategy focuses on modern ICT solutions at the initial stages of reconstruction, which potentially allows it to overcome traditional development paths.

Correlation analysis shows a positive relationship between the level of digitalization of regions and key indicators of economic efficiency, including gross regional product, employment and investment inflows. Regions with higher CRDI values tend to show stronger economic dynamics and greater innovation potential.

These results confirm the hypothesis that digital infrastructure acts as a catalyst for regional economic development. However, the strength of this relationship varies by region, which highlights the role of additional factors such as human capital, institutional capacity, and industry structure.

In general, empirical analysis confirms the existence of significant regional differences in digitalization throughout Azerbaijan. While leading regions benefit from advanced digital ecosystems, lagging regions risk being further marginalized without targeted investments in digital technologies. The Karabakh Economic Region is becoming a strategic example of how digital infrastructure can play a transformative role in sustainable regional development.

The empirical results of this study confirm that digitalization plays an important role in shaping models of regional economic development in Azerbaijan. According to international data, regions with a more developed digital infrastructure and a higher level of digital technology usage demonstrate higher economic performance and greater resilience to structural challenges. This confirms the theoretical assumption that digital infrastructure functions as a form of general-purpose capital, creating spillover effects in many sectors of the regional economy.

The observed concentration of digital development in Baku and the Absheron Economic Region is consistent with the results of research on spatial polarization in the digital economy. Similar trends have been identified in both developed and developing economies, where major urban areas disproportionately benefit from digital transformation due to the effect of agglomeration, higher concentrations of human capital, and stronger institutional capacity. In the context of Azerbaijan, this

concentration reflects historically established investment models and the centralization of economic and administrative functions.

At the same time, the intermediate level of digitalization observed in such economic regions as Ganja-Dashkesan and Sheki-Zagatala indicates the presence of new regional digital centers. These areas combine relatively developed urban centers with educational and industrial bases that contribute to the formation of digital skills and the introduction of new technologies. This conclusion indicates that digital convergence at the district level is possible when investments in digital infrastructure are complemented by human capital development and supportive regional policies.

5. Digitalization is a strategic component of regional economic transformation

The example of the Karabakh Economic Region allows us to draw particularly important conclusions. Unlike traditionally developed regions, the digitalization of Karabakh is carried out within the framework of post-conflict reconstruction, in which priority attention is given from the very beginning to intellectual infrastructure, digital governance and sustainable development. This approach reflects the transition from phased digital modernization to a more integrated development model, which potentially allows the region to bypass earlier stages of infrastructure development. International experience gained in post-conflict and newly developed regions shows that such “leap-step” strategies can bring significant long-term benefits if they are supported by stable institutions and sustained investment.

Digitalization makes it possible to modernize key industries, increase labor productivity, improve public services, stimulate innovation, attract investment and create a customer-oriented economy, which leads to the sustainable development of the region. However, the results of the study also reveal the potential risks associated with the uneven development of digital technologies. Areas with limited digital infrastructure and low levels of digital technology proficiency may face increasing economic marginalization as digital technologies become more deeply embedded in production and service provision. Without targeted policy measures, digitalization can strengthen existing regional inequalities rather than mitigate them. This highlights the importance of a differentiated digital policy that takes into account regional specificities and stages of development.

From a sustainable development perspective, the results show that digitalization can contribute to more efficient use of resources, improved provision of public services, and increased economic integration. However, these benefits are not automatic and depend on the quality of governance, the regulatory framework, and the alignment of digital strategies with broader sustainable development goals. In this regard, Azerbaijan's experience highlights the need to integrate digital infrastructure planning with regional development, environmental management, and social integration policies.

In general, it was emphasized during the discussion that digitalization should be considered not as a separate technological process, but as a strategic component of regional economic transformation. For Azerbaijan, using digital infrastructure to promote balanced regional development requires coordinated policy efforts combining investments in infrastructure, human capital development, and institutional strengthening.

6. Economic consequences of regional digitalization in Azerbaijan

The results of this study show that regional digitalization in Azerbaijan has significant economic consequences, affecting productivity, investment dynamics, labor markets and the long-term competitiveness of the region. Digital infrastructure is becoming not only an auxiliary element of economic activity, but also a key factor in structural transformations at the regional level. One of the main economic consequences of digitalization is its positive impact on productivity in the regions. Regions with a higher level of digital infrastructure development and the use of digital services demonstrate greater efficiency in production processes and service delivery. Digital technologies reduce transaction costs, expand information flows and enable companies optimize resource allocation. In Azerbaijan, this effect is particularly evident in regions with developed digital economies, where businesses benefit from improved connectivity and access to digital platforms.

In less developed regions, investments in digital infrastructure can bring significant productivity gains, offsetting geographical remoteness and limited access to markets. By reducing spatial barriers, digitalization allows regional companies to integrate into national and international markets, thereby increasing overall economic efficiency.

Digitalization significantly affects the investment attractiveness of regions. Regions with developed digital infrastructure are more likely to attract domestic and foreign investment, especially in knowledge-intensive industries and services. Reliable connectivity, access to digital government services, and the availability of ICT ecosystems reduce operational risks and increase the expected return on investment.

In the context of Azerbaijan, differences in digital technologies between regions contribute to an uneven investment structure. The concentration of investments in regions with developed digital economies reinforces existing economic imbalances. Thus, the elimination of gaps in digital infrastructure in lagging regions (digital infrastructure - full broadband Internet coverage has not yet been achieved; maturity of IT systems – regions have a low level of e-commerce; The economic integration of digital technologies into regional economies due to infrastructure gaps, although strategies until 2030 set goals for AI and Big Data with a 7-fold effect) can become an effective tool for decentralizing investment flows and stimulating regional entrepreneurship, including small and medium-sized enterprises. Digitalization is changing regional labor markets, increasing demand for digital skills and creating opportunities for new forms of employment such as remote work and digital entrepreneurship. Regions with a higher degree of readiness for digital technologies receive more diverse employment opportunities and greater flexibility in the labor market.

Conversely, regions with limited digital skills risk being excluded from emerging economic activity. This highlights the economic importance of integrating digital skills development into regional education and human resources policies. In Azerbaijan, coordinated investments in digital infrastructure and human capital can increase labor mobility, reduce regional differences in unemployment rates, and support inclusive economic growth.

Digitalization promotes structural transformation by fostering the development of new sectors of the economy and supporting diversification away from traditional activities. Digital platforms, e-commerce, and ICT-based services create opportunities for regions to develop niche economic specialization based on local comparative advantages.

For regions with a historically limited economic base, digitalization opens the way to creating more sustainable economic structures. In this regard, regional digital strategies can contribute to the emergence of innovation clusters and strengthen links between traditional industries and digital technologies.

The economic consequences of digitalization are particularly noticeable in post-conflict regions such as Karabakh. The integration of digital infrastructure into recovery efforts makes it possible to increase the efficiency of public investment management, transparency of governance, and accelerate economic recovery. Intelligent infrastructure solutions support cost-effective service delivery and enhance the long-term sustainability of renovation projects. Moreover, digitalization in Karabakh can contribute to economic reintegration by attracting investments, supporting entrepreneurship, and creating modern jobs. By introducing digital technologies into the regional development model from the very beginning, Karabakh has the potential to achieve higher economic returns on infrastructure investments and create a competitive, future-oriented regional economy.

Overall, the economic consequences of regional digitalization underscore its strategic importance for balanced regional development in Azerbaijan. Although digitalization can contribute to economic growth in the leading regions, targeted and inclusive digital policies are needed to prevent regional disparities from increasing. Bringing investments in digital infrastructure in line with regional economic priorities can enhance convergence, increase economic resilience, and support sustainable national development.

7. Conclusion and economic consequences

This study examined the level of digitalization in the regions of Azerbaijan and assessed the role of digital infrastructure in shaping regional economic development in terms of sustainable development. Using an integrated methodological framework and a consolidated regional digitalization index, the study identified significant territorial differences in digital development and highlighted the strategic importance of digital infrastructure for balanced regional growth.

Empirical evidence shows that regions with a higher level of digital infrastructure development, accessibility of digital technologies, and digital economic activity tend to show higher economic performance. Digitalization increases labor productivity in the regions, increases investment attractiveness and supports structural diversification, allowing the introduction of advanced technologies and digital business models. These effects confirm that digital infrastructure functions as a key factor in regional competitiveness and long-term economic efficiency.

At the same time, the analysis highlights the persistence of a pronounced digital divide between leading urban centers and peripheral regions. Without a targeted digital policy, this gap can lead to increased economic inequality, reduced labor mobility, and limited innovation potential in lagging regions. Thus, digitalization

alone is not enough to ensure regional convergence; it must be complemented by investments in human capital, institutional capacity, and regional development strategies.

The example of the Karabakh Economic Region illustrates the transformative economic potential of integrating digital infrastructure into post-conflict reconstruction efforts. By introducing digital technologies into urban planning, public service provision, and economic management from the initial stages of reconstruction, Karabakh can achieve higher economic returns on infrastructure investments and contribute to the development of a modern, sustainable regional economy. This approach can enable the region to overcome traditional stages of development and enter a sustainable growth trajectory consistent with national development priorities.

In terms of economic consequences, regional digitalization in Azerbaijan creates both opportunities and risks. On the positive side, digitalization supports productivity growth, stimulates investment, contributes to the modernization of the labor market and enhances the diversification of the regional economy. On the other hand, uneven digital development can increase spatial polarization and deprive less developed regions of the benefits of digital transformation.

In the light of these findings, the study concludes that digital infrastructure should be considered as a strategic economic asset within the framework of regional development policy. Policy makers should prioritize comprehensive investments in digital technologies, strengthen digital skills development, and align digital strategies with broader economic and sustainable development goals. Such an integrated approach will be essential for using digitalization as a tool for balanced regional development, economic sustainability and sustainable growth in Azerbaijan.

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