Digitalization as a Factor of Sustainable Development in Cities of the European Union

Svetlana Rastvortseva, *ORCID 0000-0002-1599-359X, HSE University, Financial University under the Government of the Russian Federation, SRastvortseva@gmail.com*

Ekaterina Panina, *ORCID 0000-0003-1860-1798, HSE University, evpanina@edu.hse.ru*

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According to data by World Bank, the global urban population has increased from 43% in 1990 to over 50% in 2007, reaching more than 56% in 2022. In the European Union (EU), this figure has exceeded 75% (World Bank, 2023). Such rapid demographic shifts introduce new challenges and threats, the resolution of which determines not only the efficiency of governance at federal, regional, and municipal levels but also overall economic growth and citizens' well-being.

The diffusion of innovations and related information consumed by urban populations significantly influences urban economies (Stroev & Pivovarov, 2022). Today, urban development and human capital enhancement are largely achieved through the implementation of digital technologies and the creation and maintenance of urban innovation systems.

In general, an innovation system – whether at the organizational, city, regional, or national level – is understood as a set of elements that enable the creation and diffusion of knowledge (Rosario et al., 2019). Information and communication technologies (ICTs) and digitalization – defined as the re-evaluation the use of ICTs for the creation and improvement of goods and services –contribute to accelerating and improving information exchange, reducing uncertainty and transaction costs.

According to the prevailing concept, an innovation system facilitates both the resolution of social problems and the strengthening of system resilience, enabling individuals, organizations, cities, regions, and nations to address emerging challenges and ensure innovative economic efficiency (Satalkina & Steiner, 2020).

Urban development and human capital enhancement are significantly driven by digitalization. However, contemporary research increasingly emphasizes the shift toward achieving social and environmental benefits, as economic gains alone can either be amplified or lost without their consideration (Elkington, 2013). The threefold impact – environmental, social, and economic – collectively enhances urban sustainability.

The imperative to conserve environmental resources drives cities to adopt new solutions, often linked to the expansion of digital technologies. For example, a study of Chinese cities found that digitalization fosters urban greening, though its impact varies by geographical location: stronger effects were observed in eastern metropolitan areas (Ma L. et al., 2023). Another study of 269 Chinese cities revealed that urban digitalization positively influences carbon emission reductions by promoting green technological innovations and optimizing industrial structures (Xia et al., 2025). The extent of this impact also depends on geographical factors, with eastern cities experiencing greater effects than western and central ones; human capital levels, where higher human capital correlates with a stronger impact; and municipal budgets, where greater financial resources for digital infrastructure investments result in increased CO2 reduction technologies.

Furthermore, digital technology adoption can reduce resource waste, reallocate labor across sectors, and lower costs (Shi et al., 2023). The transition to responsible consumption, renewable energy production, and circular economy principles can optimize urban resource allocation through digital technology advancements (Tian & Xiang, 2024).

Ensuring citizens' needs, comfort, and safety is also facilitated by digitalization. For instance, in Toronto, New York, Madrid, and São Paulo, digital offices and enhanced digital literacy have increased economic participation among people with disabilities (Kolotouchkina, 2022). A study on female entrepreneurship in Shenzhen, China, found that digitalization – particularly e-commerce – facilitates networking and open dialogue among women entrepreneurs (Luo & Chan, 2021). In education, ICT usage in university classrooms improves learning efficiency (Brevik, 2019). The COVID-19 pandemic reshaped labor relations, making remote work widely accessible through digital technologies (Veretennikova & Semyachkov, 2022). High digital skills and internet access have become "social determinants of health" (Gibbons, 2018; Schartman-Cycyk & Meisser, 2017), as job searches, housing, utility payments, and other essential services have transitioned online, limiting access for those reliant on traditional service channels. Thus, digitalization has fundamentally altered urban lifestyles.

The expansion of digital technologies has strengthened social ties within cities, facilitating collaboration between residents, local governments, businesses, and stakeholders. Digital platforms, for example, enable collective problem-solving at the community level. In Finland, such platforms have enhanced cooperation between businesses, universities, municipalities, and citizens in adopting resource-efficient services and carbon-neutral products (Anttiroiko, 2016).

From an economic perspective, digitalization positively impacts growth. Studies at the national level confirm that broadband and mobile connectivity contribute to GDP per capita growth in OECD and Middle Eastern cities and countries (Habibi & Zabardast, 2020). Digitalization has driven the expansion of high-tech industries, which are increasingly integral to urban industrial structures and optimization processes.

In the European Union urban digitalization policies are often shaped by broader agendas of the EU. In 2010, a unified digital agenda was established, aiming to ensure sustainable economic and social benefits from a single digital market built on high-speed internet and interoperable applications (European Commission, 2010). In March 2021, the EU's Digital Decade initiative outlined four key goals for 2030: enhancing digital skills, infrastructure, public services, and technology adoption in private companies (European Parliament, 2021).

Recent EU studies indicate that achieving environmental sustainability is directly linked to digitalization: the ICT sector's contribution to GDP and high digital inclusivity correlate with reduced CO2 emissions in the transportation sector (Kwilinski et al., 2023). Smart transport systems, enabled by digital technologies, optimize traffic flow, reduce congestion, and enhance fuel efficiency, thereby cutting emissions. In terms of economic sustainability, numerous studies explore the relationship between sustainable development and smart city growth. A study of 78 cities across 26 EU countries found that patent applications, ICT employment, and R&D investment—key smart city indicators—positively influence GDP (Vodă & Radu, 2018). However, factor analysis of 63 cities in Poland, Germany, and Spain showed no correlation between city size and prosperity. German cities exhibited complete heterogeneity, Spanish cities demonstrated a positive correlation between prosperity and smart initiatives, whereas Polish cities lacked both high prosperity levels and smart development (Corsini, 2016). Additionally, research in 363 urban

and 430 rural EU areas revealed that economic growth is tied to broadband internet speeds, with a more pronounced effect in rural regions still experiencing ICT scaling benefits (de Clercq, 2023). Nonetheless, the precise impact of digital technologies on the EU's Digital Decade strategy priorities remains unclear. The extent to which digitalization influences sustainable development requires further exploration. Understanding current interactions and identifying key areas for digital technology deployment can inform a catalog of best practices to help cities across the EU and beyond adapt to emerging challenges. This is particularly vital in the digitalization of urban economies, as digital technologies balance dynamic economic growth with sustainable resource management.

This study aims to determine the nature and extent of digitalization's impact on achieving sustainable urban development in the EU. It not only assesses digitalization as a component of urban systems and its role in EU economic development but also provides recommendations on leveraging European cities' experiences to shape optimal digital transformation policies for other countries and regions worldwide.

Quantitative methods were employed to analyze digitalization's impact on urban sustainability, ensuring an objective evaluation of the relationships between digital and socio-economic indicators. Regression analysis serves as the primary method, identifying statistically significant relationships between digitalization metrics and key sustainability indicators.

Dependent variables include gross urban product (GUP) per capita, higher education enrollment, and environmental sustainability. Independent variables encompass key digitalization metrics such as the number of employees in the ICT sector, fixed network speed, fixed mobile speed, and the accessibility of public and municipal services online. This selection reflects the crucial role of digital technologies in transforming economic and social environments, affecting education access, infrastructure quality, and economic growth.

Data were sourced from the Urban Data Platform Plus, supplemented by national, regional, and municipal databases where necessary. Data processing and regression modeling were conducted using R Studio. Covering 2019–2022, the study analyzed 172 EU cities, including those from Belgium (10), Denmark (6), Germany (34), Estonia (2), Spain (76), Finland (8), Croatia (4), and Latvia (2). This broad geographic scope accounts for country- and region-specific digitalization and sustainability dynamics.

Preliminary research findings demonstrate that digitalization has a significant impact on the sustainable development of European Union cities. In particular, a positive correlation has been identified between employment levels in the ICT sector, access to high-speed Internet, and key sustainability indicators such as GDP per capita and the number of students in higher education. This confirms the hypothesis that digital transformation fosters economic growth and expands opportunities for higher education.

However, assessing the impact of digitalization on environmental sustainability requires further analysis. Additionally, model specification refinement is planned, as the current set of variables may introduce endogeneity issues and distort the identified causal relationships. We are going to incorporate additional methods, such as instrumental variables, to enhance the reliability of the results.

Thus, the findings of this study confirm the importance of digitalization in achieving sustainable development goals while also emphasizing the need for a more in-depth evaluation of its environmental impact. Further research in this direction will facilitate the development of

recommendations for urban and national policies aimed at maximizing the positive effects of digital technologies while minimizing potential risks.

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