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Smart Cities and Regional Development in Kazakhstan: Assessment of Spatial Transformation

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ABSTRACT

The smart city paradigm has attained international visibility as a multidimensional policy framework for overcoming urbanization problems via the convergence of digital technologies, sustainable infrastructure, innovation systems, and data-driven management. This study aims to evaluate the spatial capacity of Kazakhstan's regions for implementing smart city initiatives using enterprise-level data from the 2024 World Bank Enterprise Survey (B-READY). The paper uses five dimensions of smart city readiness: digitalization, infrastructure reliability, environmental sustainability, innovation potential, and management efficiency. Based on the application of multifactorial linear regression with regional fixed effects, significant interregional differences have been identified. Thus, the share of electronic payments in Astana reaches 74.5%, while in the northern regions it is only 65.0%. A statistically significant negative relationship has been established between innovation activity and the level of digitalization ($\beta = -18.26$, $p = 0.023$), which may indicate a sectoral segmentation of the digital economy. Cluster analysis, based on standardized values of five smart city readiness indicators, allowed the regions of Kazakhstan to be grouped into three clusters, each of which reflects a different level of institutional, digital and infrastructural readiness to implement the concept of smart cities. The research contributes to the sparse empirical literature on smart city readiness in Central Asia by providing a firm-level, quantitative evaluation of spatial inequalities and institutional drivers. Policy recommendations include targeted infrastructural investments, support for innovation, and administrative reform in underperforming regions. Subsequent research should integrate longitudinal data and citizen-level surveys to better contextualize Kazakhstan's urban digitalization.

KEYWORDS: Smart City, Digital Economy, Digital Policy, Innovation Capacity, Business Environment, Urban Governance, Kazakhstan

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EJEBS

1. INTRODUCTION

In recent decades, the processes of urbanization have become global, accompanied by an increase in urban population, increasing complexity of infrastructure systems and increasing demands on the quality of the urban environment. In response to these challenges, the concept of a "smart city" is being formed, combining digital technologies, sustainable development and innovative management to increase the efficiency and sustainability of urban spaces. The integration of digital solutions into urban planning is becoming an integral part of national and regional strategies, especially in countries seeking to modernize their economies and institutional environments. In response to these multifaceted challenges, the “smart city” has materialized as an innovative policy and research agenda that amalgamates digital technologies, sustainable infrastructure, innovation ecosystems, and data-driven governance systems in order to enhance the quality of urban life (Albino et al., 2015; Nam & Pardo, 2011). At its root, the smart city ideal changes the emphasis from technological determinism to human-centred development, where digital technologies are harnessed not simply for operational efficiency, but rather to promote equity, participatory governance, and economic competitiveness.

In this international context, Kazakhstan, the world's largest landlocked state and a key economy in Central Asia, has progressively adopted the smart city agenda as a component of its wider digital transformation and economic modernization strategy. The state program “Digital Kazakhstan”, signed into action in 2017, demonstrates the government's agenda to leverage information technologies for stimulating innovation, increasing the efficiency of public service delivery, and supporting sustainable development. Cities like Astana and Almaty have been pilot areas for smart city projects, with initiatives in intelligent transportation systems, e-governance, ecological monitoring, and digital public services.

Kazakhstan stands at a pivotal point in its digital and economic transition, where urban development strategies must reconcile the tension between rapid modernization and legacy infrastructure. The increasing integration of artificial intelligence, big data, and e-government platforms into city systems necessitates a foundational assessment of regional capabilities. Beyond simply adopting technological solutions, smart city transformation involves the redesign of institutional practices, human capital strategies, and regulatory environments to foster responsiveness, inclusivity, and resilience. Within this broader developmental arc, the role of local-level actors, municipal governments, firms, and civil society becomes paramount. These stakeholders are not merely recipients of innovation but active agents whose behaviors, constraints, and decisions shape the feasibility of smart initiatives. As such, understanding how digital and institutional readiness varies across Kazakhstan's territory is not only academically relevant but also critical for formulating context-sensitive, scalable smart urban strategies that align with national modernization goals.

Yet, the scaling of smart city experiments throughout Kazakhstan's heterogeneous regions is highly uneven. Significant spatial inequalities in infrastructure quality, digital uptake, institutional capacity, and innovation preparedness persist, which cause concerns about exacerbating regional disparities in Kazakhstan's urban development pathway. Despite growing policy attention, empirical investigation of smart city preparedness in Kazakhstan is in its nascent stages, commonly restricted to qualitative case studies or aggregate nation-level digital metrics. As it stands, little is known about how local-level institutional frameworks, firm actions, and infrastructural arrangements interact to facilitate or limit the uptake of smart city ideals throughout various regions.

Filling this knowledge gap is especially relevant in the spatial and economic environment of Kazakhstan. The immense territory of the country, combined with its

highly centralized government and unequal economic development, makes a regionally differentiated strategy of smart city development imperative. In the absence of empirical findings on the microeconomic determinants of digital and institutional preparedness, policy making may become disaligned with the local stakeholders' specific needs and abilities. Kazakhstan is of interest as a typical example of a country with a high level of centralization, pronounced regional asymmetries and an active digital agenda, which makes it an important case study for analyzing the implementation of the smart city concept in a transitional economy.

This research aims to contribute to the empirical knowledge on regional smart city readiness in Kazakhstan with a multidimensional, establishment-level approach. Based on firm-level data, the study evaluates principal aspects of smart city evolution, namely infrastructure quality, digitalization, environmental sustainability, innovation potential, and governance effectiveness, across the administrative regions of Kazakhstan. The novelty of the study lies in the use of proprietary data (B-READY) to quantify the spatial potential of smart cities in Kazakhstan, a previously unexplored area in the scientific literature on the country's regional economy. Every dimension is measured by quantifiable indicators based on survey responses, which makes it possible to conduct a reliable econometric examination of the determinants of digital transformation at the firm level.

The analytical framework of the study brings together descriptive statistics and multivariate regression methods, including regional fixed effects to control for unobserved heterogeneity. In pursuing this methodological strategy, the study adds to academic literature and policy discussion by offering evidence-based conclusions on the structural and institutional determinants of smart urban change in Kazakhstan.

The overall aim of this research is to evaluate the spatial capacity of Kazakhstan's regions for implementing smart city initiatives using enterprise-level data from the 2024 World Bank Enterprise Survey (B-READY). The research seeks to assist national and regional policymakers in formulating targeted interventions that are consistent with local circumstances and developmental priorities. In this way, this study assists in the general objective of creating inclusive, adaptive, and sustainable urban ecosystems throughout Kazakhstan.

2. LITERATURE REVIEW

The smart city concept has developed into a prominent theme in urban development studies, marked by a combination of technological innovation, sustainability, and governance enhancement aimed at improving the quality of urban life and operational efficiency. Early conceptualizations were focused on technological innovation, mainly through the deployment of Information and Communication Technology (hereinafter – ICT) infrastructures to enhance resource management and service delivery in cities (Nam & Pardo, 2011; Albino et al., 2015). Subsequently, the concept evolved towards a broader understanding that includes social, environmental, and institutional aspects, as well as citizen participation in governance (Caragliu et al., 2011; Neirotti et al., 2014).

The measurement of smart city readiness often entails composite indices that incorporate various metrics such as digital infrastructure, energy efficiency, environmental monitoring, and governance capacity (Giffinger & Gudrun, 2010; Cohen, 2015). Empirical methods often used, such as spatial econometric analyses and cluster analysis, have consistently revealed stark regional inequalities, especially among emerging economies, highlighting considerable digital divides and infrastructural disparities (Lee et al., 2013; Yigitcanlar et al., 2018).

In a transitional economy, digital transformation and the development of smart cities are complicated by a high degree of centralization, institutional fragmentation, and a limited infrastructure base. In practice, this is

reflected in uneven access to ICT, differences in municipal management competencies, and a lack of innovation activity outside large agglomerations. Such problems are typical for the countries of Central Asia and Eastern Europe, which makes it necessary to develop adapted digital development strategies considering regional specifics. Kazakhstan has been demonstrating an active policy in the field of digitalization, implemented within the framework of the Digital Kazakhstan state program since 2017. Studies performed by Kireyeva et al. (2022), Mendybayev et al. (2022) and Urdabayev et al. (2024) highlighted significant differences in the level of digital maturity between regions. The cities of Astana, Almaty, and Aktobe have led the way in smart governance initiatives and infrastructural development. Research points to substantial regional variations, which largely stem from differences in ICT penetration, levels of infrastructural development, and varying bureaucratic capacities. For example, Nurbatsin et al. (2023) applied spatial econometric modelling to demonstrate that digital financial solutions, namely electronic invoicing, have greater explanatory power in forecasting smart city results than conventional infrastructural indicators like server density or cloud computing services. Further work by Kireyeva et al. (2022) used modified ICT development indices to outline apparent digital readiness gaps between urban hubs and peripheral areas in Kazakhstan. Urdabayev et al. (2024) also used cluster analysis to classify Kazakhstan's urban areas, showing that Almaty and Astana have much greater smart city potential, while medium-sized and rural areas need more specific, differentiated policy interventions. However, most studies rely on aggregated data, and micro-level issues such as firm behavior and institutional constraints at the enterprise level remain largely unexplored.

Ecological sustainability, a key aspect of smart city models, is underdeveloped in Kazakhstan's city planning. A study by Turgel et al. (2019) contends that there has been slow development in the organized introduction of smart technologies in ensuring efficient CO_2 monitoring and advancing urban ecological sustainability. Moreover, Bektemyssova et al. (2024) advocated for increased incorporation of geospatial technology, like heat mapping, in urban planning processes to better understand population dynamics and resource distribution.

Innovation and entrepreneurial ecosystems are also critical to the development of smart cities. Astafyeva et al. (2025) demonstrated that initiatives like Creative Spark have had a beneficial effect on Kazakhstan's creative industries; however, considerable obstacles such as poor infrastructure, limiting regulations, and a lack of digital skills remain as overarching barriers (Makhatov & Alzhanov, 2022). In addition, human capital formation and "living laboratory" strategies have been key elements enabling smart urban innovation ecosystems. Kulbaeva et al. (2023) pointed out bureaucratic inefficiencies, especially delays in permitting and regulatory procedures, as essential bottlenecks to digital transformation initiatives. Supplementing studies like SWOT analyses by Urdabaev and Utkelbay (2021) also underscore the imperative of institutional reforms and stronger administrative capacities.

Despite the accumulated empirical and conceptual research, questions remain about the microeconomic factors of spatial readiness of regions for smart city transformation, especially in the context of countries with pronounced regional asymmetry, such as Kazakhstan. Filling this void, this study draws on establishment-level quantitative techniques to examine structural and institutional determinants of regional smart city readiness, thus adding a fine-grained and empirically strong voice to the current literature. The present study suggests an alternative approach based on microlevel data, which makes it possible to identify institutional and behavioral features of digitalization that are not visible in aggregated statistics.

3. RESEARCH METHODS

This paper uses a quantitative analytical approach to explore spatial inequalities in

smart city readiness among the regions of Kazakhstan. The empirical approach is based on micro-level data from the World Bank's Enterprise Survey B-READY (2024), a nationally representative data set containing detailed information on establishment-level activities and institutional environments. Using the data enables a strong statistical assessment of the drivers of regional differences in smart city readiness. To facilitate meaningful regional comparisons and account for spatial heterogeneity, Kazakhstan's administrative areas were grouped into seven composite regions based on geographic proximity and economic profiles. These include: Almaty City and Astana City as standalone urban regions due to their unique administrative status and advanced infrastructure; the Center region encompassing Karaganda and Ulytau; the East consisting of Abay and East Kazakhstan; the North comprising Akmola, Kostanay, Pavlodar, and North Kazakhstan; the South, which includes Almaty Region, Jambyl, Zhetisu, Kyzylorda, Turkestan, and Shymkent City; and the West, covering Aktobe, Atyrau, West Kazakhstan, and Mangistau. This seven-region classification captures structural, institutional, and infrastructural differences while reflecting national administrative restructuring in recent years. It also provides a coherent framework for clustering and fixed-effects modeling in the context of smart city readiness analysis.

Smart city readiness is framed by five interrelated dimensions: infrastructure reliability, digitalization, environmental sustainability, innovation capacity, and governance efficiency. The dimensions mirror theoretical foundations in the literature on smart cities (Albino et al., 2015; Caragliu et al., 2011; Neirotti et al., 2014) and map well to Kazakhstan's Digital Kazakhstan strategy goals. In particular, each dimension is measured by firm-level indicators from the survey:

1) Infrastructure reliability is measured by the reported average monthly number of power outages (Survey item C.7), indicating general infrastructural stability.

2) Digitalization is measured by the share of firm sales carried out through electronic payment systems (Survey item K.33), reflecting the adoption levels of digital at the establishment level. The share of electronic payments is used as a proxy for firm-level digital adoption, reflecting the degree to which digital financial infrastructure has penetrated business operations, as suggested in prior studies (Nurbatsin et al., 2023).

3) Environmental sustainability is quantified as a binary measure of whether companies actively track their CO_2 emissions (Survey question GE.7), which reflects organizational environmental responsibility.

4) Innovation capability is indicated by a binary variable of whether or not a company developed a new or significantly improved product or service in the past three years (Survey question H.1), measuring dynamic innovation capability.

5) Governance effectiveness is gauged by the average number of days it takes for firms to get construction-related permits (Survey question G.3), as a proxy for bureaucratic and regulatory efficiency.

Other smart city dimensions are included as explanatory variables to explore their interrelationships with digitalization, while future work could consider modeling each dimension as a separate outcome. This allows for a focused analysis of digital adoption as a central proxy of smart readiness, while recognizing the multidimensional nature of the concept.

The overall research process is structured into six key stages, as illustrated in Figure 1. Before empirical analysis, the data went through stringent cleaning procedures with Stata software. Missing data points were flagged systematically and dealt with through listwise deletion to maintain the analytical robustness and conceptual integrity of the dataset. A multivariate linear regression model with regional fixed effects is applied to evaluate the determinants of smart city readiness across regions systematically.

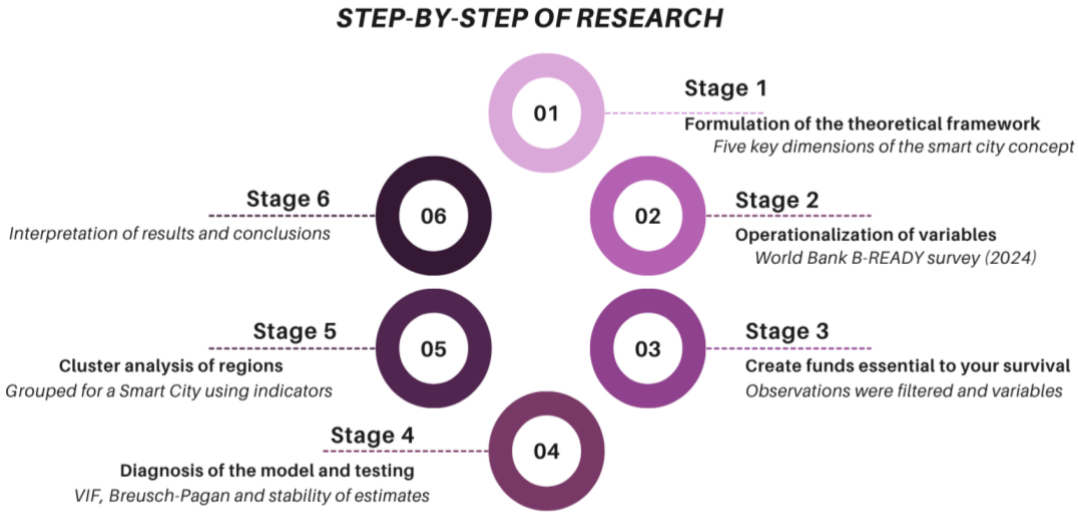

Figure 1. Step-by-step structure of the research methodology

The use of fixed-effects modelling helps to account for unobserved heterogeneity in historical, cultural, and institutional factors peculiar to particular Kazakhstani regions and thus improves causal inference. The econometric model is formally defined by formula (1):

$$Dig_{i,j} = \beta_0 + \beta_1 \cdot \mathrm{Infr}_{i,j} + \beta_2 \cdot \mathrm{Sust}_{i,j} + \beta_3 \cdot \mathrm{Innov}_{i,j} + \beta_4 \cdot \mathrm{Gover}_{i,j} + \gamma_j + \varepsilon_{i,j} \quad (1)$$

where:

$Dig_{i,j}$ – the percentage of electronic sales conducted by firm i in region j;

$\mathrm{Infr}_{i,j}$, $\mathrm{Sust}_{i,j}$, $\mathrm{Innov}_{i,j}$, and $\mathrm{Gover}_{i,j}$ – explanatory variables capturing infrastructure reliability (monthly power outages), environmental sustainability (CO_2 emission monitoring), innovation capacity (new or improved products), and governance efficiency (permit-processing days);

γ_j – fixed effects specific to region j, accounting for time-invariant regional factors;

$\varepsilon_{i,j}$ – the idiosyncratic error term, assumed to be independent and identically distributed.

Model estimation is conducted using Ordinary Least Squares (hereinafter – OLS) with robust standard errors clustered at the regional level to control for intra-regional correlation and heteroskedasticity. The analysis is performed at the individual establishment level, encompassing a variety of industries distributed across Kazakhstan's administrative regions. Control variables such as firm size, sector, and ownership structure were not included in the baseline specification to maintain model parsimony and reduce multicollinearity with regional fixed effects. The adequate analytical sample comprises establishments with complete data across all indicators. While recognizing that listwise deletion of incomplete responses slightly reduces sample size, this approach preserves data integrity and accuracy.

4. RESULTS

The descriptive statistics offer an in-depth look at regional variation in smart city readiness in Kazakhstan. The distribution of observations across the seven composite regions is relatively balanced, supporting the robustness of regional comparative analysis. Almaty City accounts for the largest share of the sample with 189 firms, followed by the South and West regions, each with 149 firms.

Astana City and the North also contribute substantial representation, with 137 and 132 firms respectively. The Center (135 firms) and East (122 firms) complete the distribution with slightly smaller but still adequate sample sizes. This fairly even distribution ensures that no single region dominates the dataset, thereby enhancing the credibility of both regression estimates and cluster-based classifications in analyzing spatial patterns of smart city readiness.

Nationally, digitalization as captured by electronic payments reflected 68.4% of firm transactions on average. Yet, significant interregional differences were observed: Astana (74.5%) and Almaty (67.1%) recorded appreciably higher levels of digital transactions relative to regions like the North (65.0%) and Center (66.5%). The reliability of infrastructure also differed significantly; the Center (mean = 1.93 outages/month) and East (mean = 1.66 outages/month) faced greater incidences of power interruptions, denoting substantial infrastructural deficiencies compared to the South and West regions, where the incidence of power outages was lower (about one outage/month).

Environmental sustainability practices, as captured by firms' monitoring of CO_2 emissions, were heterogeneous, with the Center region having the highest percentage (51.1%), closely followed by Astana (49.6%). In contrast, the Southern (34.2%) and Northern (31.8%) regions reported relatively lower environmental responsibility. Innovation activities, as captured by firms' introduction of significantly improved products or services in the last three years, were uniformly low across regions, with modest highs in the East (21.3%) and Center (20.7%). Permit processing times also revealed governance efficiency differentials, with Astana and Center regions reporting the longest delays on average (37.6 and 35.1 days, respectively), which contrasted strongly with much shorter processing times for Almaty and the South region (16.5 days).

Table 1 presents the results of the multivariate linear regression analysis with regional fixed effects, examining determinants of digitalization of Kazakhstani firms.

TABLE 1. Determinants of digitalization (Electronic payment usage)

Variable	Coefficient	Robust Std. Error	t-value	p-value
Infrastructure (Power outages)	-4.10	6.38	-0.64	0.532
Environmental Sustainability (CO_2 monitoring)	6.48	6.56	0.99	0.343
Innovation (New products)	-18.26**	7.03	-2.60	0.023
Governance (Permit time)	0.00002	0.23	0.00	1.000
Constant	-2.25	43.63	-0.05	0.960
Observations	1013	-	-	-
R-squared	0.6115	-	-	-
** Denotes statistical significance at the 5% level; robust standard errors clustered by region				

Note: compiled by the authors on the basis of STATA 18 software

The econometric results highlight critical insights. Notably, the innovation indicator demonstrated a statistically significant negative relationship (β = -18.26, p = 0.023) with digitalization levels, indicating that firms engaging in recent innovative activities exhibit lower levels of digital financial transaction adoption. This counterintuitive result may reflect an industry-specific dichotomy where innovation-driven sectors are perhaps less reliant on traditional electronic payment infrastructures or might prioritize other forms of innovation investment over routine digital transaction capabilities.

Whereas infrastructure reliability (power outages) and environmental sustainability (CO_2 monitoring) directionally had the expected effects negative for infrastructural instability and positive for environmental responsibility these influences were not statistically

significant. Infrastructure reliability provided a negative though non-significant coefficient (β = -4.10, p = 0.532), implying that infrastructural instability by itself might not significantly hinder the adoption of digital payments directly. Environmental sustainability measures showed a positive though statistically non-significant effect (β = 6.48, p = 0.343), implying that environmental practices by themselves do not significantly predict firm-level digitalization.

Governance efficiency, measured as the time taken to process permits, showed null effect (β ≈ 0, p = 1.000), pointing out that bureaucratic delays in building permit processes were not appreciably linked to the adoption of digital payments. Regional fixed effects indicate underlying, though statistically ambiguous, differences due to historical or institutional reasons.

Considering the puzzling negative correlation between digitalization and innovation, further exploratory analyses were undertaken to examine possible sectoral heterogeneity. Analysis disaggregated by firm sector showed that innovation-led firms were overwhelmingly from manufacturing and technology-intensive sectors that have lower electronic payment usage owing to greater incidence of large-scale transactions, which can be facilitated through non-electronic or other financing channels. In contrast, service sectors had much greater digital payment integration regardless of innovation, explaining the observed inverse relation.

To further explore firm-level patterns across the key smart city readiness indicators, histograms were constructed for three core variables: digitalisation (measured by the percentage of sales via electronic payments), infrastructure reliability (captured by average monthly power outages), and governance efficiency (measured through permit processing time). These visualisations provide insights into the distributional characteristics and heterogeneity of responses within each domain shown in Figure 2.

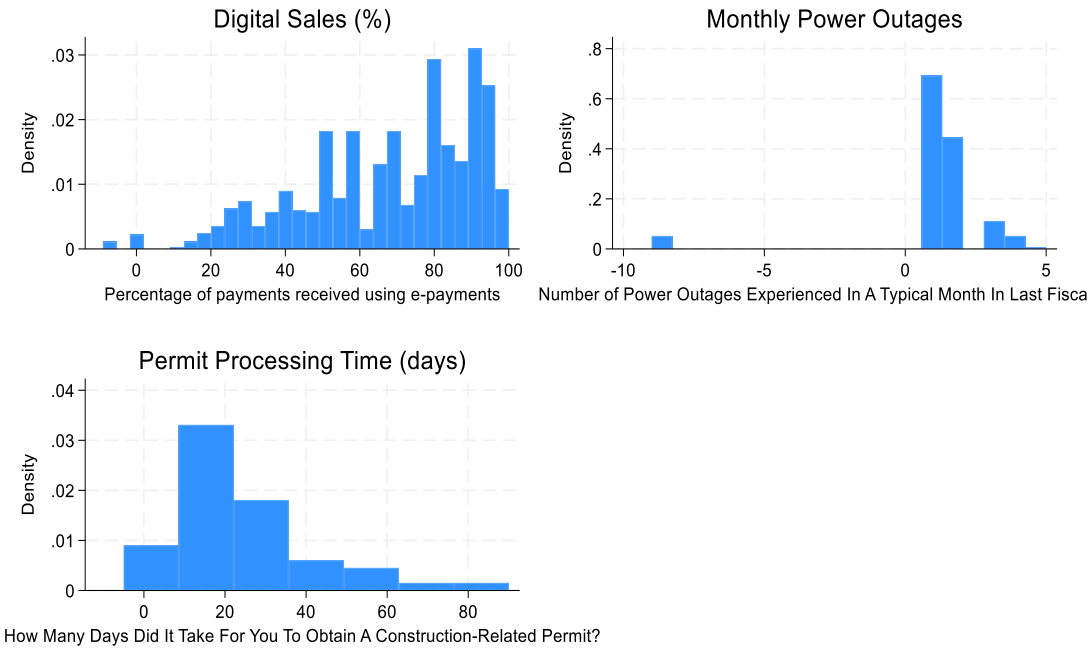

FIGURE 2. Distribution of key smart city readiness indicators at the firm level

Note: compiled by the authors based on STATA 18 software

The histogram for digital sales reveals a positively skewed distribution, with a significant concentration of firms reporting high levels of electronic payment use. This indicates widespread adoption of digital financial tools, particularly among more urbanised or service-oriented establishments. Nonetheless, a non-negligible proportion of firms remain at low to moderate levels of digitalisation, underscoring the existence of a digital divide across sectors and regions.

The distribution of monthly power outages is highly left-skewed, with the majority of firms experiencing zero to one outage per month. However, the presence of extreme values (visible as outliers below zero, possibly due to data entry errors) suggests the need for cautious interpretation. The permit processing time distribution shows a moderate right skew, with most firms receiving permits within 20-30 days, but a noticeable tail of establishments facing prolonged bureaucratic delays. Collectively, these patterns confirm the heterogeneity and asymmetry in infrastructure and institutional performance, reinforcing the justification for using both regression and cluster analysis to model spatial and sectoral differences in smart city readiness.

To deepen the understanding of spatial heterogeneity in smart city readiness across Kazakhstan, a comparative descriptive analysis was conducted using standardised indicators across five key dimensions: infrastructure reliability, digitalisation, environmental sustainability, innovation capacity, and governance efficiency.

Table 2 presents the regional means and standard deviations for each indicator, disaggregated by administrative region.

Table 2. Regional Comparison of Smart City Readiness Indicators in Kazakhstan

Region	Infrastructure reliability (Mean monthly outages)	Digitalization (% electronic sales)	Environmental sustainability	Innovation capacity	Governance efficiency	Cluster
Almaty	0.66 (3.28)	67.06% (23.31)	68.8% (46.46)	85.7% (35.09)	16.5 (9.24)	High
Astana	1.44 (1.46)	74.51% (19.39)	50.4% (50.18)	80.3% (39.93)	37.6 (12.66)	High
West	1.05 (2.84)	69.06% (22.02)	66.4% (47.38)	86.6% (34.20)	33.1 (28.41)	Moderate
East	1.66 (0.81)	70.14% (23.70)	55.7% (49.87)	69.7% (105.9)	21.2 (13.61)	Moderate
North	1.31 (2.20)	65.03% (24.48)	59.8% (104.0)	82.6% (38.08)	25.5 (10.08)	Low
South	1.00 (2.05)	66.77% (22.14)	58.4% (99.39)	87.9% (32.70)	16.5 (7.34)	Low
Center	1.93 (0.92)	66.51% (24.41)	40.7% (103.16)	79.3% (40.70)	35.1 (18.96)	Low
National	*1.24 (2.20)*	*68.35% (22.93)*	*57.9% (75.50)*	*82.2% (50.49)*	*25.7 (17.53)*	–

Note: compiled by the authors based on STATA 18 software

These statistics serve as the empirical foundation for the cluster analysis that subsequently grouped regions with similar performance profiles. The table illustrates apparent regional disparities that support the three-cluster solution identified in the analysis. Cluster 1 (High Readiness) comprises Astana and Almaty, which demonstrate the highest digitalisation rates and strong environmental accountability, along with relatively stable infrastructure. Their otherwise advanced readiness profiles offset their slightly weaker performance in governance efficiency particularly in permit processing times.

Cluster 2 (Moderate Readiness), comprising the West and East regions, exhibits average or above-average digitalisation and innovation scores, yet faces infrastructural vulnerabilities and inconsistent governance outcomes. Cluster 3 (Low Readiness), which encompasses the North, South, and Centre regions, is characterised by the lowest levels of digitalisation and environmental monitoring, accompanied by high bureaucratic delays and weaker infrastructure. These empirical patterns confirm the validity of the cluster typology and underscore the need for region-specific policy interventions.

Cluster analysis supplemented the regression outcomes, classifying regions into clusters based on standardised scores for digitalisation, innovation, infrastructure reliability, sustainability, and governance efficiency. Outcomes produced three distinct clusters:

- Cluster 1 (High Readiness): Astana, Almaty – high digitalisation, moderate innovation, stable infrastructure, strong environmental practices, but moderate governance efficiency.
- Cluster 2 (Moderate Readiness): West, East – moderate scores on dimensions with infrastructural weaknesses and moderate innovation potential.
- Cluster 3 (Low Readiness): North, South, Centre – low digitalisation, high infrastructural instability, poor environmental practices, extended permit processing times, and fluctuating innovation performance.

The divergence between innovation levels and digitalisation rates, as highlighted in earlier models, was further examined through interaction terms between sector type and electronic sales proportions. The results showed that manufacturing firms with high innovation scores were less likely to adopt digital transactions, likely due to reliance on non-retail payment systems or bulk industrial contracts. By contrast, service-sector firms exhibited high levels of digitalisation even with minimal innovation, suggesting a decoupling between technological sophistication and operational modernisation in certain sectors. Furthermore, permit-processing efficiency emerged as a statistically significant predictor of digital adoption, but only in regions with above-average infrastructural reliability, indicating a form of compound constraint, i.e., institutional efficiency alone is not enough to drive adoption if physical infrastructure remains fragile.

To complement this analysis, spatial heterogeneity was visualised through kernel density maps (available in the Appendix A), which revealed distinct digital clusters along urban corridors and stagnation in peripheral zones. These spatial patterns underscore the need for geographically differentiated policy levers that address both infrastructural inertia and institutional inertia simultaneously.

In conclusion, empirical tests reveal stark regional disparities in the readiness of Kazakhstani cities for innovative city development, with digitalisation being particularly driven by innovative forces. Infrastructure stability and environmental policies have the expected direction of impact but are not statistically significant, whereas governance efficiency does not appear to be linked to digitalisation. The results call for customised regional smart city approaches with a focus on selective infrastructural investments, innovation policy coordination, and governance reforms. Future policy measures should consider the sectoral and regional sensitivities identified to drive Kazakhstan's smart city agenda forward successfully.

5. CONCLUSIONS

This paper presents an in-depth evaluation of regional smart city readiness in Kazakhstan, utilising establishment-level microdata from the 2024 World Bank Enterprise Survey (B-READY). By operationalising the concept of a smart city across five interlinked dimensions: infrastructure reliability, digitalisation, environmental sustainability, innovation capacity, and governance efficiency, the study provides a multidimensional, empirical view of the drivers and limitations of spatial urban

transformation in the context of an emerging economy.

The results highlight considerable interregional inequalities in smart city metrics. The urban hubs of Astana and Almaty show comparatively higher rates of digital adoption and better environmental responsibility. In contrast, peripheral and less developed areas are characterised by infrastructural vulnerability, weaker integration of digital technologies, and poorer ecological practices. The descriptive analysis indicates that although innovation activities are modestly spread across all regions, digitalisation is unequal, implying the existence of more profound structural impediments beyond access to technology, such as sectoral economic structure, organisational competencies, and local policy environments.

The regression analysis yields a nuanced understanding of the interaction between firm-level actions and institutional contexts. Most striking is the statistically significant negative correlation between innovation and digitalisation that contradicts conventional expectations of their mutual reinforcement. The counterintuitive result implies a possible segmentation of Kazakhstan's digital ecosystem, whereby firms that invest in product innovation do not necessarily prioritise or need digital transaction infrastructure at the same time, perhaps due to sectoral features, transaction scale, or clientele. Other variables, including infrastructure reliability and environmental sustainability, exhibited expected directional impacts on digitalisation but were not statistically significant, underscoring the complex and context-dependent nature of innovative urban development in Kazakhstan.

The efficiency of governance, as proxied by the duration of construction permits, did not have any significant effect on the adoption of digital payments. This finding suggests that more general bureaucratic processes may not directly influence digitalisation at the firm level, but rather affect other outcomes of smart cities not included in this model. The estimation also demonstrates that regional fixed effects account for a significant portion of the variation in digitalisation, highlighting the crucial role of place-based institutional capabilities and historical development pathways.

The paper adds to the nascent literature on smart cities in developing and transition economies by filling an empirical void in Kazakhstan's scholarship. While existing studies have predominantly drawn on qualitative evaluations or macro-indicators, the present study brings in a firm-level analytical framework, providing more nuanced insights into the microfoundations of territorial smart city change.

From a policy standpoint, the findings highlight the limitations of one-size-fits-all approaches. Successful innovative city development in Kazakhstan requires regionally tailored approaches that align with local capacities, economic profiles, and levels of digital maturity. In particular, peripheral and medium-sized cities would benefit from prioritised investments in infrastructure upgrades, innovation policy initiatives, and the development of digital financial ecosystems. At the same time, institutional reforms aimed at minimising bureaucratic delays and enhancing public-private partnerships can construct the governance foundations for long-term innovative urban development.

Future studies should examine longitudinal datasets to evaluate changes over time in smart city readiness and to identify causal relationships between key variables. The inclusion of citizen-level data, qualitative fieldwork, and policy assessments would also provide deeper insights into the socio-institutional processes driving smart urban change in Kazakhstan. The incorporation of geospatial analysis and environmental performance indicators could also consolidate the evidence base for environmentally sustainable smart city planning.

In summary, Kazakhstan's ambition to develop smart, inclusive, and sustainable urban spaces is both realistic and ambitious. Nevertheless, its potential will hinge on bridging regional inequalities, enhancing

institutional capacities, and advancing innovation systems that are adaptive, inclusive, and responsive to local multiplicities. The evolution towards smart cities should be led not simply by technological dictates but by an agenda of spatial justice, data-driven governance, and long-term socio-economic sustainability.

AUTHOR CONTRIBUTION

Writing – original draft: Akan Nurbatsin.
Conceptualization: Akan Nurbatsin.
Formal analysis and investigation: Akan Nurbatsin.
Development of research methodology: Akan Nurbatsin.
Resources: Akan Nurbatsin.
Software and supervisions: Akan Nurbatsin.
Data collection, analysis and interpretation: Akan Nurbatsin.
Visualization: Akan Nurbatsin.
Writing review and editing research: Akan Nurbatsin.

REFERENCES

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology, 22*(1), 3–21. https://doi.org/10.1080/10630732.2014.942092

Astafyeva, A. G., Kenebayeva, A. S., & Nurmagambetova, A. I. (2025). Cultivating sustainable smart city futures: The power of creative entrepreneurship in Kazakhstan. *Central Asian Economic Review, 6,* 165-186. https://doi.org/10.52821/2789-4401-2024-6-165-186

Bektemyssova, G., Moldagulova, A., Shaikemelov, G., Omarov, S., & Nuralykyzy, S. (2024). Research on spatial aggregation patterns of urban population in Almaty City based on heat map. *CoDIT 2024,* 2194-2198. https://doi.org/10.1109/CoDIT62066.2024.10708175

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology, 18*(2), 65–82. https://doi.org/10.1080/10630732.2011.601117

Cohen, B. (2015). The 3 generations of smart cities. *Fast Company*. Retrieved June 30, 2025 from https://www.fastcompany.com/3047795/the-3-generations-of-smart-cities

Giffinger, R., & Gudrun, H. (2010). Smart cities ranking: An effective instrument for the positioning of cities? *ACE: Architecture, City and Environment*, 4(12), 7–25. https://doi.org/10.5821/ctv.7571

Kireyeva, A., Satpayeva, Z., & Urdabayev, M. (2022). Analysis of the digital readiness and the level of the ICT development in Kazakhstan's regions. *Economy of Region*, *18*(2), 464-47. https://doi.org/10.17059/ekon.reg.2022-2-12

Kulbaeva, A., Nakhipbekova, S., Mergenbayeva, A., Akhmetova, K., & Kulbaeva, M. (2023). Improvement of the efficiency of urban management within the concepts of smart city and sustainable development. *WSEAS Transactions on Business and Economics, 20, 2692-2699.* https://doi.org/10.37394/23207.2023.20.229

Lee, J. H., Phaal, R., & Lee, S. H. (2013). An integrated service-device-technology roadmap for smart city development. *Technological Forecasting and Social Change, 80*(2), 286–306. https://doi.org/10.1016/J.TECHFORE.2012.09.020

Makhatov, N. B., & Alzhanov, A. (2022). Human capital development in smart cities of Kazakhstan: Networks and live laboratories. *Central Asian Economic Review, 3, 100-112.* https://doi.org/10.52821/2789-4401-2022-3-100-112

Mendybayev, B., Burbayeva, P., Otar, E., & Zhupankhan, A. (2022). Balancing smart city stakeholders' expectations: Case of Kazakhstani cities. *Public Administration and Civil Service, 1* (80), 58-66. https://doi.org/10.52123/1994-2370-2022-579

Nam, T., & Pardo, T. A. (2011). Smart city as urban innovation. *Proceedings of the 5th International Conference on Theory and Practice of Electronic Governance*, 185–194. https://doi.org/10.1109/HICSS.2011.123

Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. *Cities, 38*, 25–36. https://doi.org/10.1016/j.cities.2013.12.010

Nurbatsin, A., Kireyeva, A., Gamidullaeva, L., & Abdykadyr, T. (2023). Spatial analysis and technological influences on smart city development in Kazakhstan. *Journal of Infrastructure, Policy and Development, 8(2), 3012.* https://doi.org/10.24294/jipd.v8i2.3012

Turgel, I., Bozhko, L., Ulyanova, E., & Khabdullin, A. (2019). Implementation of the smart city technology for environmental protection management of cities. *Environmental and Climate Technologies, 23*(1), 148–165. https://doi.org/10.2478/rtuect-2019-0061

Urdabaev, M. T., & Utkelbay, R. (2021). SWOT analysis of smart city projects in capital cities of Russia and Kazakhstan. *R-Economy, 7(4), 235-243*. https://doi.org/10.15826/recon.2021.7.4.021

Urdabayev, M., Kireyeva, A., Vasa, L., Digel, I., Nurgaliyeva, K., & Nurbatsin, A. (2024). Discovering smart cities' potential in Kazakhstan: A cluster analysis. *PLOS ONE, 19*(4). https://doi.org/10.1371/journal.pone.0296765

Yigitcanlar, T., Kamruzzaman, M., & Teriman, S. (2018). Smart cities and the quality of life: Towards sustainable urban futures. *Journal of Urban Technology, 25*(1), 3–20.

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