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ENGINEERING SMART GOVERNANCE SYSTEMS AND E-GOVERNMENT SERVICES FOR URBAN SUSTAINABILITY: A SYSTEMS-BASED APPROACH TO SDG-ALIGNED URBAN EFFICIENCY

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Abstract

Smart cities, a crucial answer to urbanization's mounting difficulties, are transforming ecosystems worldwide. This study examines how smart infrastructure, digital connectivity, e-government services, renewable energy integration, and intelligent governance policies affect urban efficiency in Pakistan. Studying urban characteristics and identifying sustainable development solutions are crucial in light of the expansion of urbanization. The study employed a two-stage least squares (2SLS) regression technique, using quarterly data from 1996Q1 to 2022Q4. The results show that digital connection, e-government service adaptability, renewable energy integration, and quality of life enhance urban efficiency. Digital connectivity enables the effective management of urban processes, services, and infrastructure, making cities more livable, resilient, and ecologically friendly. Government online services improve management and empower citizens. Renewable energy helps cities become more resilient and solve environmental issues. Nevertheless, governments must collaborate to overcome structural impediments that may hinder these projects. Smart infrastructure, digital connectivity, e-government services, and renewable energy sources may help Pakistan achieve fair and sustainable urban development. Policymakers should support sustainable urban expansion to secure a prosperous future for future generations.

INTRODUCTION

The idea of "smart cities" has transformed cityscapes, ushering in the digital era. Since the 1990s, the notion has evolved to reflect changing technology and culture (Tokmakoff & Billington, 1994). Cities are embracing smart infrastructure, digital connectivity, and efficient governance to increase efficiency and attract ICT enterprises (Shetty, 1997). By 2050, scientists expect almost two-thirds of the world's population to live in cities (United Nations, 2020). Cities provide opportunities and challenges for this population shift due to their anticipated usage of over 70% of the world's energy and their significant environmental implications, such as GHG emissions. These urban issues need smart infrastructure and imaginative solutions (Desdemoustier et al., 2019). Connectivity and communication are essential to smart cities (Sun & Poole, 2010). Smart cities offer virtual and actual social connections, demonstrating "intelligent communities," constructing intelligent infrastructure is difficult due to conflicting stakeholder interests, a lack of resources, technical knowledge, public apathy, unreliable finance, and unstable administrations (Jayasena et al., 2020). Cruz and Sarmento (2017) and Selim et al. (2018) recommend public-private cooperation to tackle these challenges. ICT has played a pivotal role in enhancing people's quality of life and fostering community harmony. In e-government services, 'sustainability' involves efficiently managing resources to meet the needs of individuals, businesses, workers, and governments (Joshi & Islam, 2018). The UN's 2030 Sustainable Development Goals (SDGs) prioritize effective governance and modern public administration (Glass & Newig, 2019). Nurdin (2018) advocates for the long-term sustainability of e-government systems, but other researchers have raised concerns about decentralization, cost-effectiveness, and economic growth. Despite government and academic efforts, the lack of a consensual definition makes smart city research difficult. According to Giffinger et al. (2007), smart cities need a technologically advanced economy, educated and skilled people, efficient governance, intelligent transportation systems, sustainable practices, and a decent quality of life. These areas include public safety, economic competitiveness, educational accomplishment, social connection, labor market adaptability, quality of life, transportation efficiency, effective governance, and resource management (Zhang et al., 2018). Urban resilience theory emphasizes smart cities' capacity to adapt and thrive despite adversity. Renewable energy integration (REI) and smart infrastructure investment (SINV) technologies are suggested to make cities more disaster-resistant. SINV employs innovative technology like sensor networks to react to unforeseen events, whereas REI uses renewable energy to reduce dependency on conventional power and boost climate resilience. These improvements help cities adapt and recover, creating resilient and sustainable urban ecosystems (Mossey et al., 2018). Citizen-centric governance theory for smart cities (CCGT-SC) is another essential paradigm for innovative city development. E-government services adoption (EGSA) and smart governance policies (SGP) demonstrate how digital technology may make public administration more accessible, transparent, and collaborative. This CCGT-SC real-world study examines how EGSA and SGP affect public engagement and agency. This theoretical framework provides practical ideas for integrating EGSA and SGP into public administration and smart cities.

The research goals focus on the relationship between smart city characteristics, urban efficiency, and quality of life. The first question is how cities' investments in adaptable infrastructure influence operational efficiency and resilience. It further enhances our understanding of how smart infrastructure investment (SINV) affects city efficiency, which drives this research query. It examines how these investments help cities adapt to energy distribution, emergency response, and traffic management issues, improving their sustainability and effectiveness. Second, digital connection, e-government services adoption (EGSA), and renewable energy integration (REI) impact on urban efficiency are examined to demonstrate the interconnectedness of technology and governmental advances. Digital connectivity improves urban services and public engagement by allowing real-time data sharing. REI promotes renewable energy to reduce environmental impact and boost resource efficiency, while EGSA streamlines administrative processes to improve service delivery and governance transparency. Considering these characteristics together helps explain how policy and technological solutions improve city efficiency and sustainability. Finally, analyzing the effects of digital connectivity, smart infrastructure investment, EGSA, REI, and smart governance policies (SGP) on urban efficiency—moderated by quality of life—shows innovative city programs' socio-economic impacts. Smart governance principles make it simpler for sectors to collaborate and make choices to enhance innovation and public well-being. The research examines how these components affect urban efficiency, considering quality of life metrics like social cohesion, health, and education to fully understand innovative city programs' revolutionary potential.

The study has the following research objectives:

I. To explore the role of investments in building intelligent infrastructure and improvements in digital connectivity to enhance urban efficiency within Pakistan's evolving urban landscapes.

II. To analyze the effects of adopting e-government services and integrating renewable energy sources on the efficiency and sustainability of urban environments and

III. To assess how effective implementation of intelligent governance policies interacts with quality of life factors influencing urban efficiency.

This investigation is essential for smart cities and urban development. As the globe urbanizes rapidly, resource conservation, environmental preservation, and urbanites' quality of life are top issues (Zhang & Ren, 2024). To promote urban efficiency and address these critical issues, one must understand the complex relationships between intelligent infrastructure, digital connectivity, e-government services, renewable energy integration, and efficient governance policies. By examining these features, the study seeks to help stakeholders, urban planners, and legislators create smart, ecologically sustainable cities for future generations.

2. Literature Review

Strategic urban upgrading has made wise infrastructure investment increasingly crucial. Zaidan et al. (2022) suggest that smart infrastructure improves city functioning, including transit networks and energy-efficient buildings. Brown et al. (2019) emphasize data's role in intelligent infrastructure investment decisions. This strategy optimizes resource consumption. Ismail et al. (2023) argued that smart cities rely on digital connectivity for communication and information sharing. Allam et al. (2022) stressed the relevance of 5G technology in enabling IoT and transforming urban connectivity. Kumar et al. (2020) examine how digital connection affects citizen involvement and improves service delivery and city life. Berglund et al. (2020) define "smart cities" as extensive metropolitan areas that employ technology to enhance city living. Sensor networks and real-time data processing increase resource management, energy consumption, and city functionality. Smart cities can only advance with a good digital infrastructure. Kasznar et al. (2021) found that the system fosters economic development via digital transformation, convergent innovation, and intelligent upgrading, driven by technical advancements and information networks. Qiao et al. (2022) argued that climate change and digital disruption need us to rethink how we develop and plan cities. Smart cities have been criticized for being excessively tech-centric. This approach has made intelligent cities a top urban innovation priority (Yang et al., 2021). Based on the given discussions, the study's first hypothesis is as follows:

H1: Smart infrastructure investment and digital connectivity are positively related to Urban efficiency.

E-government has risen fast due to the need to update governmental services and engage more people online. E-government efforts have been studied for legislative frameworks, user-centric design, and technology infrastructure (Jejeniwa et al. 2024; Tiika et al. 2024). E-government may revolutionize transparency, efficiency, and public involvement, but digital divide issues and security concerns must be addressed (Hujran et al., 2023). Wilson et al. (2020) revealed that manufacturing technologies and materials research are improving solar photovoltaics. Smart grids and demand-side management were examined by Su et al. (2021) to improve renewable energy systems. Renewable energy sources must be integrated into the economy and society. Wilson et al. (2017) examined how renewable energy projects affect nearby communities. They focused on how these developments benefited employment creation and economic growth. Hoicka et al. (2021) and Carbajo and Cabeza (2021) examined how participatory strategies increase community renewable energy installation. Academic discussions on intelligent cities have prioritized urban efficiency. Bibrian (2018) examines how data analytics, the IoT, and other technologies may improve municipal planning and resource management. Urban efficiency programs may improve the environment and citizens' quality of life. A key component of effective city design is studying circular economies, which optimize resource usage and minimize waste. Bibri and Krogstie (2017) suggest combining digital governance with renewable energy to maximize urban efficiency. Data-driven energy management and governance collaborations are emphasized as possible synergies (Bibri, 2021). Based on the cited literature, the second hypothesis of the study is as follows:

H2: E-government service adoption and renewable energy integration are anticipated to yield a positive impact on urban efficiency

Cities have changed due to smart governance efforts. Smart governance relies on data-driven decision-making and public interaction (Bibri, 2020). Dong and Liu (2023) found that policy frameworks affect local government adoption of emerging technologies like IoT and AI. Effective governance is crucial to city residents' well-being. According to Cardullo and Kitchin (2018), digitally implemented citizen-centric policies may increase access to services, inclusiveness, and well-being. Goel and Vishnoi (2022) believe smart governance initiatives may improve cityscapes by promoting ecological sustainability. Wu et al. (2020) noted that data governance standards improve urban systems, including energy distribution and traffic management. Intelligent governance policies typically need citizen participation. Participatory governance affects community empowerment and social cohesiveness, according to Caputo et al. (2023). Rodríguez-Navas et al. (2021) explored how digital platforms improve government-constituent communication, increasing responsiveness and accountability. Despite its advantages, intelligent governance concepts are challenging to execute. Eom and Lee (2022) state that data privacy and digital inequality are significant obstacles. Kim et al. (2022) examine overcoming obstacles to improve intelligent governance policies. They promote standardized frameworks and collaboration. The final hypothesis of the study is as follows:

H3: Smart governance policy and quality of life are anticipated to have a positive impact on urban efficiency

Smart cities represent a pivotal approach to addressing the challenges posed by rapid urbanization worldwide. As urban populations grow, cities are increasingly turning to smart infrastructure, digital connectivity, e-government services, renewable energy integration, and intelligent governance policies to enhance efficiency and sustainability (Das, 2024). This study focuses on Pakistan's urban context, aiming to understand how these components collectively impact urban efficiency and contribute to sustainable development. Previous research has underscored various facets of smart cities but also revealed several research gaps that merit further investigation (Zhu et al. 2024; Grossi & Welinder, 2024). One notable gap is the need for more empirical studies that specifically examine the implementation and effectiveness of smart infrastructure investments in enhancing urban efficiency in developing countries like Pakistan. While there is extensive theoretical literature on the benefits of smart infrastructure, empirical evidence from specific contexts such as Pakistan is limited. For instance, studies by Kaššaj & Peráček (2024) and Sharifi et al. (2024) have highlighted the potential benefits of smart infrastructure and digital connectivity in urban settings, but they predominantly focus on developed economies. Another critical gap pertains to the integration and impact of e-government services and renewable energy in enhancing urban efficiency in developing country contexts. Research by Iong & Phillips (2023) discusses the transformative potential of e-government services but often lacks detailed case studies or empirical data from countries facing unique challenges like Pakistan. Similarly, while renewable energy integration is recognized as a crucial component of sustainable urban development (Chen, 2023; Woon et al. 2023), there is a dearth of studies exploring its practical implementation and effectiveness in enhancing urban efficiency in specific developing country contexts. Furthermore, there remains a gap in understanding how smart governance policies, tailored to local contexts, can effectively support and sustain the benefits derived from smart city initiatives. Studies such as those by Giuliodori et al. (2023) and Esposito et al. (2024) emphasize the importance of governance frameworks in realizing smart city goals, yet insights into their application and impact in countries like Pakistan are limited.

Addressing these gaps is essential not only for advancing academic knowledge but also for informing policy and practice. By filling these gaps, this study aims to contribute to the broader discourse on smart cities and urban efficiency, particularly in developing countries. It seeks to provide empirical evidence and practical insights that can guide policymakers, urban planners, and stakeholders in Pakistan towards more effective strategies for sustainable urban development. Ultimately, understanding how smart infrastructure, digital connectivity, e-government services, renewable energy integration, and intelligent governance policies interact in Pakistan's urban landscape will facilitate more informed decision-making and support the transition towards smarter, more resilient cities globally.

3. Theoretical framework

Urban Resilience Theory states that cities may thrive despite technological and environmental changes. Smart infrastructure may help communities prepare for public health emergencies, economic downturns, and natural disasters (Zhu et al., 2019). Intelligent transportation networks and smart grids optimize resources and provide real-time monitoring (Alhamed et al., 2022). Diversifying energy sources may help cities survive interruptions and preserve energy supplies during crises. Urban resilience theory suggests that AI, IoT, and data analytics make cities more robust to misfortune (Agboola & Tunay, 2023). These technologies can help cities survive, adapt, and recover (Ernstson et al., 2010). The Citizen-Centric Governance Theory for Smart Cities (CCGT-SC) states that smart governance policies and adaptation of e-government services (EGSA) must work together to grow smart cities (Ernstson et al., 2010). Digital technology may empower and involve individuals in public administration. In order to provide an inclusive, accessible, and responsive governance system with services ranging from information dissemination to transactional processes, EGSA uses digital platforms to provide government services. It provides fair access to public services via digital literacy training and user-friendly interfaces, according to CCGT-SC (Sengboon, 2018). Smart infrastructure investment must involve cutting-edge technology like IoT, AI, and data analytics to simplify decision-making. A solid data governance system is needed to make proactive, data-driven choices that fulfill citizen needs. This guarantees ethical and responsible use of citizen data. Digital platforms that enable public discussion on government activities, community-driven projects, and policy-making may empower citizens (Mossey et al., 2018). To adopt CCGT-SC and create a governance structure that reflects the community's aspirations, continuous communication, community engagement, and inclusive decision-making are needed. This approach promotes CCGT-SC principles of openness, diversity, and public engagement.

4. Data and Methodology

Table 1 shows the list of candidate variables used in the study. The data is taken from the World Bank (2023) data base. The quarterly data from 1996 to 2022 is used for empirical analysis.

Table 1: List of Variables

Variable Type	Variable Name	Description	Indicator
Dependent Variable	Urban Efficiency (UEF)	Measures the comprehensive effectiveness of urban services, infrastructure, and resource management.	Population with access to clean fuels and technologies for cooking (%)
Independent Variables	Smart Infrastructure Investment (SINV)	Investment in smart technologies for urban infrastructure, such as smart grids and intelligent transportation systems.	Research and Development (R&D) Expenditure (% of GDP)
	Digital Connectivity (DC)	Availability and quality of digital infrastructure, including high-speed internet access and mobile network coverage.	Internet Users (% of Population)
	E-Government Services Adoption (EGSA)	Utilization of digital platforms for accessing government services and interacting with public agencies.	Automated teller machines (ATMs) (per 100,000 adults)
	Renewable Energy Integration (REI)	Percentage of renewable energy sources integrated into the urban energy grid, contributing to sustainability in resource management.	Renewable Energy Consumption (% of Total Final Energy Consumption)
	Smart Governance Policies (SGP)	Implementation and effectiveness of policies promoting smart governance, including data-driven decision-making and citizen engagement.	Government Effectiveness Index
	Quality of Life (QLIFE)	Overall quality of life in urban areas, considering factors like healthcare, education, safety, and cultural amenities.	Adult Literacy rate (% of people ages 15 and above)

Source: World Bank (2023).

The impact of smart infrastructure, digital connectivity, e-government services, renewable energy integration, and intelligent governance policies in Pakistan presents a unique and captivating case study. The selection of Pakistan is not arbitrary, but rather a result of its multifaceted aspects, including its critical geopolitical significance, dynamic economy, and diverse demographics, which make it a compelling subject for investigation. With its strategic location and economic and geopolitical importance, Pakistan is a fascinating case study and a potential source of inspiration. Its role as a vital link in regional and global economic networks, as demonstrated through regional trade agreements and international commerce, underscores the potential to learn how geopolitics impacts and is affected by smart city activities (Razia et al. 2023). Pakistan's rapid urbanization is not just a local phenomenon, but a global issue that presents both opportunities and risks. As more people move to cities, the need for efficient, sustainable, and robust urban systems becomes more pressing (Aslam et al. 2021). Pakistan's diverse cities, from the bustling metropolises of Lahore and Karachi to the fast-developing villages, provide a rich fabric for researching smart city policy and technologies, making this case study highly relevant to the field of urban development (Vinod Kumar, 2023; Iyengar, 2017).

Another complex element is Pakistan's demography. Due to its young and growing population, the city needs modern urban services and infrastructure. This demographic change makes smart city technology demonstration and deployment perfect (Rathore & Ghani, 2023). Pakistan's varied economy, including old and emerging enterprises, is an intriguing case study for studying technology and urban development. This nation's commitment to economic change and progress, as indicated by its extensive infrastructure and technology investments, makes it ideal for studying smart city plans (Asghar et al. 2023). Pakistan's renewable energy integration is instructional for sustainable urban development (Xu et al. 2023). Smart city technology may improve environmental sustainability, as proven by the country's attempts to incorporate renewable energy into its urban energy infrastructure. Pakistan is an excellent example of how renewable energy integration may improve urban resilience and reduce fossil fuel use, two critical variables in global sustainability (Javaid et al. 2024). Pakistan's socio-cultural and historical context might help explain urban expansion. Pakistani cities' rich cultural heritage and evolution affect their planning and management. Smart city development may help us understand how old and modern may coexist to make cities more efficient and enjoyable (Shaikh, 2023).

4.1. Econometric Framework

The study employed the number of statistical techniques for parameter estimates, which helps to reach some conclusive policy implications.

4.1.1. Two-Stage Least Squares (2SLS) Regression

Endogeneity in regression models is commonly handled using two-stage least squares (2SLS) regression. According to Land and Dean (1992), endogeneity in ordinary least squares (OLS) regression arises when the error term and one or more independent variables are correlated. 2SLS excels at endogeneity via instrumental variables or simultaneous equation models. Keane and Neal (2023) define 2SLS as dividing the endogenous variable in half. First, predict the endogenous variable using instrumental parameters. The second step uses this stage's predicted values as independent variables in the central regression equation. In the first phase of the research, instrumental variables were utilized to eliminate endogeneity in urban efficiency and its predictors. The second stage uses anticipated values as predictors for reliable, objective assessments. Equation (1) shows the 2SLS formulation of the model, i.e.,

- First Stage Least Squares (OLS) Regression:

$$UEF = \beta_0 + \beta_1 SINV_t + \beta_2 DC_t + \beta_3 EGSA_t + \beta_4 REI_t \quad (1)$$

- Two Stage Least Squares (2SLS) Regression:

$$UEF = \beta_0 + \beta_1 SINV_{t-1} + \beta_2 DC_{t-1} + \beta_3 EGSA_{t-1} + \beta_4 \quad (2)$$

Where,
UEF shows urban efficiency
SINV shows smart infrastructure investment
DC shows digital connectivity
EGSA shows e-government services adaptation
REI shows renewable energy integration
SGP shows smart governance policies
QLIFE shows quality of life
't' shows time period
't-1' shows first time lagged, and
Ɛ shows error term.

4.1.2. Time Series Forecasting Using Spectral Analysis

At the heart of spectral analysis is the Fourier transform, a mathematical tool that converts time-domain signals into frequency-domain ones. This transformation gives analysts a clear view of the amplitude and phase of frequency components, enabling a deeper understanding of the time series structure (Serani et al., 2023; Yang et al., 2023). As Wei et al. (2024) demonstrated, spectral analysis is instrumental in identifying periodic oscillations, seasonality, and cyclical patterns in time series data. Spectral analysis extracts usable information from noisy data in signal processing. Spectral analysis may reveal hidden patterns in time series forecasting that typical approaches overlook.

5. Results and Discussion

Descriptive statistics show the distribution and variability of key variables (Table 2). UEF ranges from 4.50 to 29.30, with a mean of 13.97 and a standard deviation 7.89. Average digital connectivity (DC) is 9.75, with a standard deviation 5.76 and a range of 1.32 to 21.04. E-Government Service Adoption (EGSA) ranges from 0.74 to 11.14 with a standard deviation of 4.04 and a mean of 5.53. Renewable Energy Integration (REI) has a standard deviation of 2.39 and an average of 47.06 (42.10–51.54). The Quality of Life (QLIFE) scale ranges from 49.87 to 59.13, with a mean of 54.67 and a standard deviation of 3.28. SINV data has a standard deviation of 0.14, a mean of 0.29, and a range of 0.12 to 0.63. Smart Governance Policies (SGP) have a 0.13 standard deviation and a -1.05 to -0.48 range, with an average value of -0.70. .

Table 2: Descriptive Statistics of the Variables

Variables	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
UEF	24.80	4.50	29.30	13.96	7.88	62.21
DC	19.72	1.32	21.04	9.74	5.76	33.20
EGSA	10.40	0.74	11.14	5.52	4.03	16.28
REI	9.44	42.10	51.54	47.05	2.38	5.70
QLIFE	9.26	49.87	59.13	54.67	3.28	10.76
SINV	0.52	0.12	0.63	0.28	0.14	0.02
SGP	0.57	-1.05	-0.48	-0.70	0.12	0.01

Source: Author's estimate.

Table 3 shows the correlation matrix, demonstrating a positive link between urban efficiency and digital connectivity (r = 0.984). This information shows that urban efficiency and digital connectivity are growing. When E-Government services (EGSA) were implemented, the positive correlation between digital connectivity (r = 0.937) and urban efficiency (UEF) (r = 0.974) was not just a statistical finding but a testament to the transformative power of these services. This emphasizes the necessity of effective digital infrastructure and cities in promoting E-Government, and the potential they hold for urban development. Renewable Energy Integration (REI) had negative associations with urban development indices such UEF, DC, EGSA, and QLIFE, indicating trade-offs when integrating renewable energy sources. This shows the challenges of integrating renewable energy sources while balancing digital connectivity, urban efficiency, e-government adoption, and quality of life. QLIFE was substantially linked (r=0.824–0.915) with UEF, DC, and EGSA. These findings show that e-government services, digital connectivity, and smart urban design improve living circumstances. Smart Infrastructure Investment (SINV) had negative correlations with UEF, DC, EGSA, and REI, suggesting that investing in innovative infrastructure may improve urban efficiency, digital connectivity, E-Government services, and renewable energy sources at cost and benefit. Since REI and smart governance regulations are negatively correlated (r = -0.464), focusing on intelligent governance laws may reduce the installation cost of renewable energy systems. The results emphasize the necessity for strategic and coordinated smart city planning and governance by showing the complex interaction between various factors affecting urban development.

Table 3: Correlation Matrix

Variables		UEF	DC	EGSA	REI	QLIFE	SINV	SGP
UEF	Pearson Correlation	1						
	Sig. (2-tailed)	----						
DC	Pearson Correlation	.984**	1					
	Sig. (2-tailed)	.000	----					
EGSA	Pearson Correlation	.974**	.937**	1				
	Sig. (2-tailed)	.000	.000	----				
REI	Pearson Correlation	-.599**	-.625**	-.688**	1			
	Sig. (2-tailed)	.003	.001	.000	----			
QLIFE	Pearson Correlation	.857**	.824**	.915**	-.738**	1		
	Sig. (2-tailed)	.000	.000	.000	.000	----		
SINV	Pearson Correlation	-.352	-.276	-.307	-.230	-.042	1	
	Sig. (2-tailed)	.100	.203	.154	.292	.850	----	
SGP	Pearson Correlation	-.037	-.030	.080	-.464*	.309	.646**	1
	Sig. (2-tailed)	.868	.890	.716	.026	.151	.001	----
**. Correlation is significant at the 0.01 level (2-tailed).								
*. Correlation is significant at the 0.05 level (2-tailed).								

Table 4 shows the 2SLS estimates and found the positive association between digital connectivity and urban efficiency is supported by the fact that more internet usage leads to better urban efficiency in a country. Yang et al. (2023) found that digitalization in China and regional collaborative innovation affect Beijing-Tianjin-Hebei industrial eco-efficiency. This shows the relevance of digital infrastructure in industrial development and environmental repercussions, which will help regions attempting to improve their digital infrastructure. Internet connectivity is crucial to municipal efficiency in contemporary cities. Internet connection and other digital technology have transformed municipal operations, resource management, and public participation. Better digital connectivity has several advantages for urban efficiency beyond productivity. Barro (1997) found that intelligent infrastructure investment increases digital connectivity. Smart technology helps cities manage resources, maintain infrastructure, and provide public services, making this investment crucial. Garcês et al. (2022) indicated that cities that fully embrace digital transformation enhance municipal infrastructure and operational efficiency, which boosts urban efficiency indicators.

Table 4: Two-Stage Least Squares Regression Estimates

Variables		Unstandardized Coefficients		Beta	t-value	Sig.
		B	Std. Error			
Equation 1	(Constant)	-14.143	6.993	----	-2.023	0.060
	DC	0.774	0.065	0.565	11.876	0.000
	EGSA	0.989	0.160	0.506	6.184	0.000
	REI	0.318	0.087	0.096	3.659	0.002
	QLIFE	2.189	0.235	0.911	9.295	0.000
	SINV	-30.709	14.423	-0.563	-2.129	0.046
	SGP	-0.422	1.470	-0.007	-0.287	0.778
Model Summary and ANOVA						
	R-square	0.997	F-statistics	818.088		
	Adjusted R-square	0.996	Prob.value	0.000		

Source: Author's estimate.

The role of e-governance services in driving social and economic progress is underscored by the strong correlation between their adoption and urban efficiency. This view is supported by Sanina et al.'s (2021) research, which emphasizes how digital government transformation (DGT) is revolutionizing public administration and governance. Their study provides theoretical and empirical evidence of how DGT can enhance socioeconomic outcomes by aligning government policies with public needs. The potential of data-driven decision-making and digital platforms in addressing urban issues and reducing waste is a testament to the potential of DGT in improving local government efficiency.

Sustainable development and environmental stewardship make renewable energy integration (REI) essential to urban efficiency. Data shows a good link between the two variables. Barman et al. (2023) and Asghar et al. (2023) stress the complementary aspect of renewable energy deployment and urban efficiency advances. Their study demonstrates that communities that invest in renewable energy receive more money to build municipal infrastructure. Effective regulations and technologies are needed to use renewable energy to achieve urban efficiency, energy security, and environmental sustainability.

Quality of Life measures urbanites' socioeconomic well-being and livability. Improving living conditions in urban areas is vital since QLIFE positively correlates with urban efficiency ($\beta = 2.189$, $p < 0.001$). Juan et al. (2023) discuss how smart city initiatives reduce emissions, optimize resource use, and encourage this link to increase urban well-being. Their results demonstrate the importance of smart city metrics in green city design and living standards.

However, smart infrastructure investment (SINV) to achieve urban efficiency goals is challenging and involves complex trade-offs. According to Yin and Hai-Ying (2023), an empirical study by Barberis &

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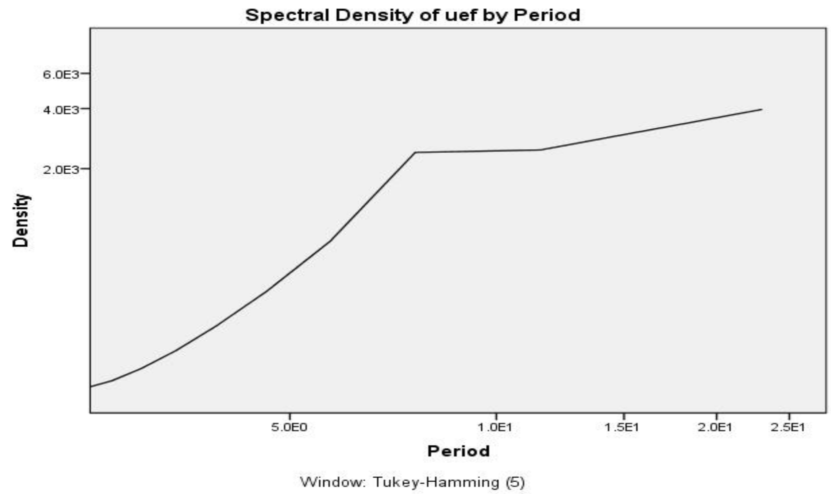
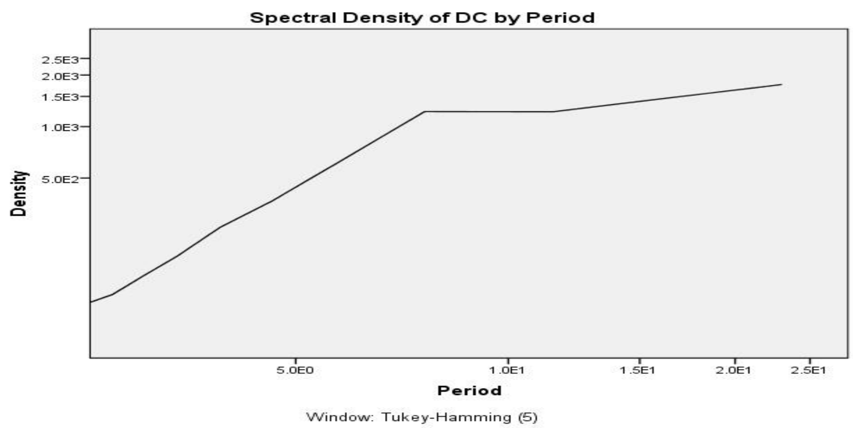
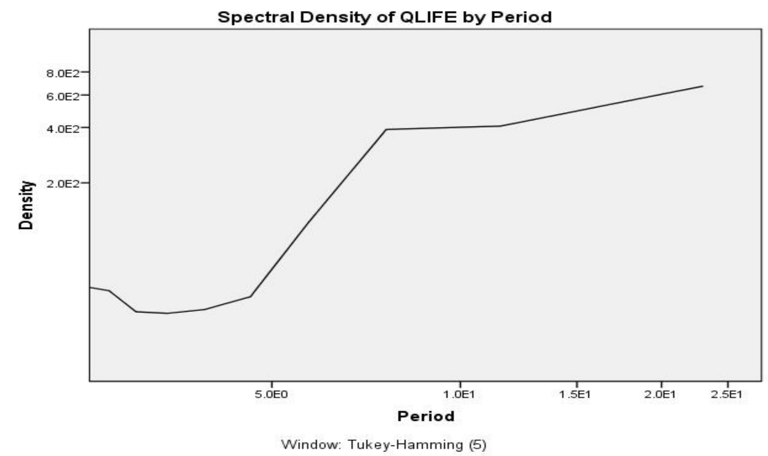
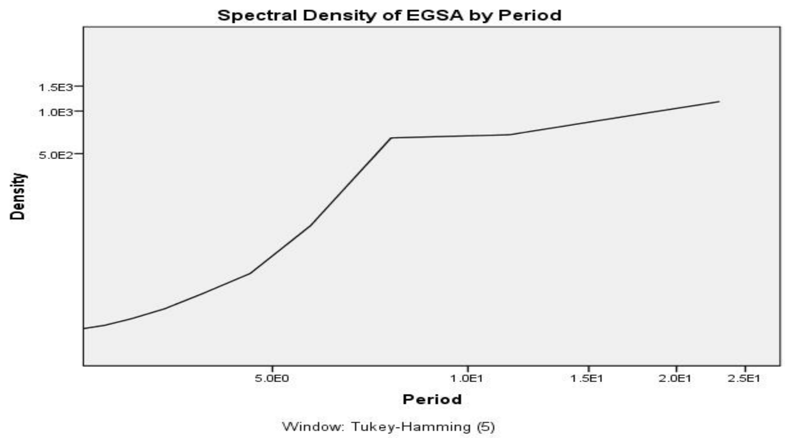
Huang (2008), and Baker & Wurgler (2006), strategic investments in smart infrastructure may bring economic and logistical issues despite improving urban operating efficiency. Optimizing smart infrastructure expenditures requires careful resource allocation and alignment with urban development goals since SINV negatively impacts urban efficiency (β = -30.709, p = 0.046). Berglund et al. (2020) concluded that smart transportation systems, energy-efficient buildings, and digital infrastructure significantly reduced city traffic, energy consumption, and waste.

With the rise of "smart urban governance"—an integrated government framework that considers physical space, institutions, and new technologies—urban planning is changing. Park and Yoo (2022) suggest a comprehensive city planning model that considers all areas of city life to increase municipal government efficiency and engagement. Their study reveals cultural, political, and economic factors affect governance and smart city outcomes. Cities may use data analytics, IoT technologies, and citizen-centric governance models to improve urban efficiency via informed decision-making and responsive policy frameworks. This helps them overcome governance issues. Using spectral analysis, Figure 1 shows the predicted changes in numerous crucial parameters over 25 years.






Spectral Density of QLIFE by Period
Density
8.0E2
6.0E2
4.0E2
2.0E2
5.0E0
1.0E1
1.5E1
2.0E1
2.5E1
Period
Window: Tukey-Hamming (5)


Spectral Density of EGSA by Period
Density
1.5E3
1.0E3
5.0E2
5.0E0
1.0E1
1.5E1
2.0E1
2.5E1
Period
Window: Tukey-Hamming (5)

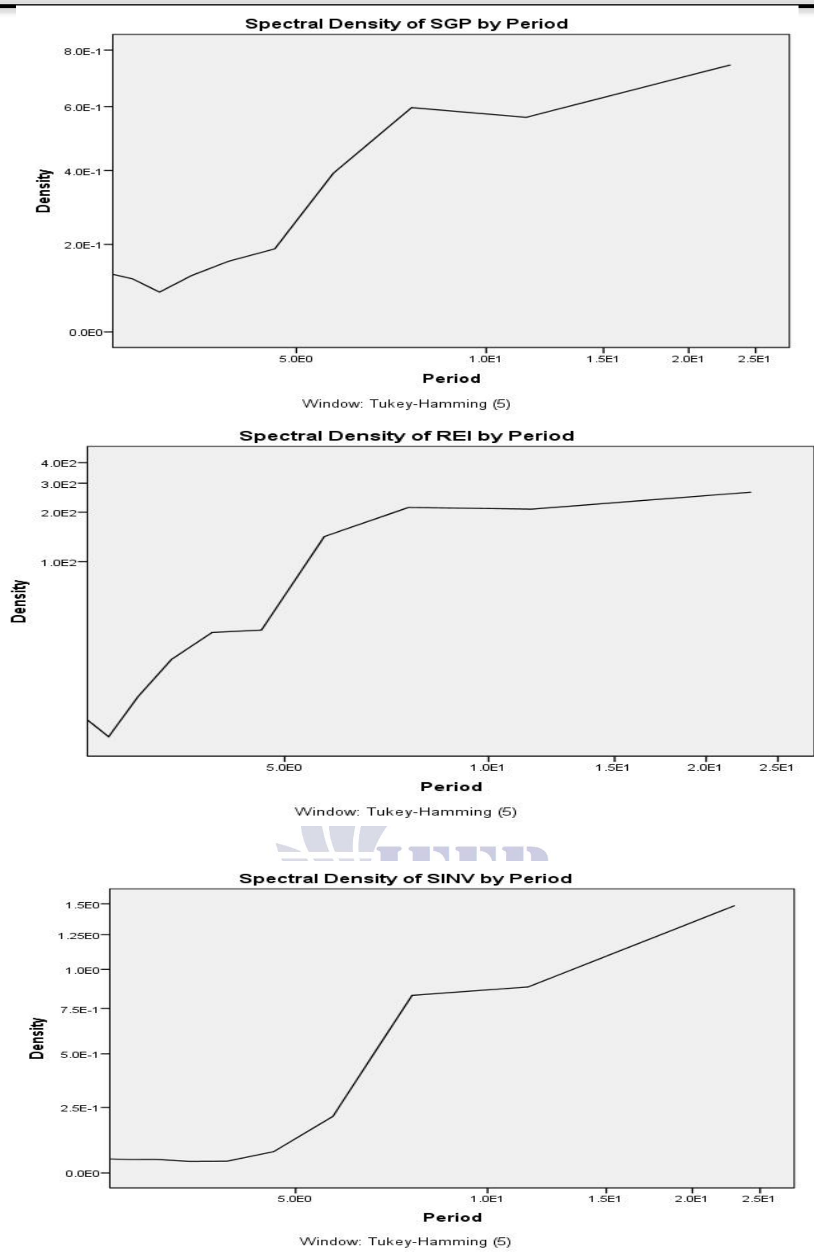


Figure 1: Spectral Analysis

Source: Author's estimate.

Continuously rising urban efficiency may suggest greater resource management, infrastructural efficiency, and environmental impact in cities. Sustainable development and city planning are global aims, and this movement supports them. Another trend is digital connection, which indicates the growing availability of the internet and seamless integration of technology. Due to this growth, communities will have greater knowledge, economic opportunities, and communication networks. It shows how the digital revolution is altering communication and business. The rise in quality of life predicts improvements in environmental quality, safety, healthcare, and education, which are essential for community health and development. Smart infrastructure investment is likely to rise as infrastructure efficiency and resilience increase. This venture addresses urban concerns including traffic congestion, energy usage, and waste management with cutting-edge technology. Renewable energy integration is improving, indicating a shift toward greener power production. This trend is essential for climate change mitigation and environmental sustainability. E-government use is rising, indicating a move toward digital governance. This reform will increase transparency, improve public service delivery via digital platforms, and expedite administrative processes. Smart governance policy first declines but subsequently increases. This suggests that governance structures will improve with time, but policy implementation will be problematic initially. It shows how social and technological changes impact government across time. The spectrum analysis forecasts that digital governance, sustainable infrastructure, quality of life, connection, and efficiency will improve. These achievements demonstrate the progress toward smarter, more sustainable cities that meet 21st-century challenges. Constant monitoring and adapting policies are needed to accomplish these predicted improvements and ensure sustainable urban expansion over 25 years.

6. Conclusions and Policy Recommendations

This study examined how smart governance, digital connectivity, e-government services, sustainable energy integration, and sustainable infrastructure have improved urban efficiency in Pakistan. The findings show that digital connectivity, e-government service adoption, renewable energy use, smart governance policy implementation, and quality-of-life improvements boost urban efficiency. More financing for green infrastructure will help Pakistan's urban efficiency. Smart infrastructure projects may boost municipal efficiency via strategic investment by replacing outdated infrastructure and using new technology to streamline operations. Renewable energy helps cities reduce energy shortages and environmental issues, promoting sustainable urban expansion and investment. These initiatives need to work on promoting decision-making and civic engagement due to bureaucratic red tape and technological constraints. These hurdles must be overcome for innovative governance initiatives to improve urban efficiency.

The following are the short-term, medium-term, and long-term policy recommendations for smart urban development, i.e., short-term policy recommendations include investments in digital infrastructure and initiatives to promote e-government expertise and acceptance. Short-term incentives like subsidies or tax exemptions are also needed to promote renewable energy. With simplified bureaucracy, urban development, and smart infrastructure projects may be executed faster. The study recommends standardizing smart infrastructure and sponsoring digital skills initiatives in the medium term. R&D in renewable energy sources beyond wind and solar may improve energy sustainability and security. Data analytics may help government agencies utilize resources more efficiently and make better-informed choices. For smart city programs to endure in the long run, politicians must pass strict data privacy, cybersecurity, and public-private partnership laws. They must also invest in smart technology, governance model research, and innovation to create new city solutions. Integrated smart governance systems that aggregate urban data will enable real-time monitoring and adaptive decision-making.

Government agencies must improve their institutional capabilities for smart urban management. Promoting community engagement via inclusive methods like participatory budgeting and digital feedback channels help smart city programs retain public support and ownership. These policy measures should promote sustainable urban development in Pakistan by using smart technology, improving governance, and encouraging inclusive growth over time.

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