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The role of digital citizen participation in the development of smart cities in Serbia

Uloga digitalne participacije građana u razvoju pametnih gradova u Srbiji

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Article info

Original scientific paper

Received:
30 June, 2025
Revised:
5 November, 2025
23 March, 2026
Accepted:
21 April, 2025
Published online: 24 April, 2026

DOI:
https://doi.org/10.71159/bizinfo260006C

UDC/ UDK:
711.45:004.78(497.11)

Abstract

This paper investigates the relationship between digital citizen participation and the development of smart cities in Serbia's major urban centers. The study aims to determine how core forms of digital engagement - such as social network activity, participation in online forums, and the use of mobile applications - affect key dimensions of smart city advancement, including digital infrastructure, smart governance, and service innovation. Quantitative data were collected from 332 respondents in five cities using a structured online questionnaire. Statistical analysis incorporated descriptive methods, cluster analysis, ANOVA, and multiple regression. Results indicate strong, statistically significant associations between digital engagement and all major smart city dimensions, especially among respondents from Belgrade and Novi Sad. The identification of three distinct clusters also reveals considerable regional disparities in digital maturity and smart city adoption. These findings highlight the urgent need for targeted policies and ongoing educational programs to foster inclusive and sustainable smart urban transformation across Serbia.
Keywords**:** *citizens, digital participation, innovation, smart cities, Serbia*

Sažetak

Ovaj rad istražuje odnos između digitalne participacije građana i razvoja pametnih gradova u najvećim urbanim sredinama Srbije. Cilj istraživanja je da utvrdi u kojoj meri ključni oblici digitalnog angažmana - poput aktivnosti na društvenim mrežama, učešća na online forumima i korišćenja mobilnih aplikacija - utiču na osnovne dimenzije razvoja pametnog grada, uključujući digitalnu infrastrukturu, pametnu upravu i inovativne usluge. Kvantitativni podaci su prikupljeni od 332 ispitanika iz pet gradova pomoću strukturisanog onlajn upitnika. Statistička obrada obuhvatila je deskriptivnu analizu, klaster analizu, ANOVA i višestruku regresiju. Rezultati pokazuju snažne i statistički značajne veze između digitalnog angažmana i svih glavnih dimenzija pametnog grada, posebno kod ispitanika iz Beograda i Novog Sada. Identifikacija tri klastera otkriva izražene regionalne razlike u digitalnoj zrelosti i usvajanju pametnih gradskih rešenja.
Ključne reči*: građani, digitalna participacija, inovacije, pametni gradovi, Srbija.*

1. Introduction

Contemporary urban development faces the challenges of accelerated digitalization, increasingly complex population needs, and growing demands for more efficient, sustainable, and inclusive city management. The concept of smart cities has, in recent years, taken a central place in both the theory and practice of urban planning worldwide, including in Serbia. Smart cities imply the use of advanced information and communication technologies (ICT), digital services, and innovations to improve quality of life, enhance the efficiency of public services, and strengthen the sustainability and resilience of urban environments. In this process, digital citizen participation - citizens' involvement in governance, decision-making, and information exchange through digital platforms - emerges as one of the key factors for successful smart urban transformation.

Although numerous cities in Serbia are making efforts to improve digital infrastructure and implement smart solutions, the degree of digital citizen participation and its

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impact on smart city development remain insufficiently explored. Regional disparities, the digital divide, and variations in the availability of digital resources further complicate the process of inclusive transformation. The aim of this paper is to analyze the relationship between digital citizen participation and smart city development through empirical research conducted in the five largest urban centers in Serbia. Special attention is given to identifying key dimensions of digital engagement, evaluating statistically significant relationships and differences among respondent clusters, as well as providing recommendations for advancing smart city policy in Serbia.

This approach not only enables a better understanding of the current situation and challenges, but also helps define guidelines for future public policies and strategies aimed at strengthening digital participation and accelerating the development of smart, sustainable, and inclusive cities.

2. Literature review

The smart city concept has emerged in contemporary literature as a response to the challenges of urbanization, climate change, energy efficiency, and the need for improved management of urban resources. Smart cities are defined as urban spaces that leverage information and communication technologies (ICT) to enhance citizens' quality of life, service efficiency, and community sustainability (Batty et al., 2012; Albino et al., 2015). In modern discourse, smart city development implies a holistic approach encompassing digital infrastructure, e-governance, green technologies, participatory management, and transparency (Angelidou, 2017). Giffinger et al. (2007) identify six dimensions of a smart city: smart economy, people, governance, mobility, environment, and lifestyle, which provide an integrated evaluation framework. According to Borowczak et al. (2020), modern smart cities are multidimensional entities, incorporating human (social), automated (technological), and collective (Agora) aspects, thus surpassing traditional phases of urban development. In this regard, the smart city concept has shifted from a technology-oriented model toward a socio-technological framework that includes citizens as active participants.

Recent academic research increasingly emphasizes citizen engagement as a central component of smart governance, not merely as a technological complement but as a key driver of effective, sustainable, and legitimate urban transformation. Almulhim (2025) demonstrates that smart city initiatives relying exclusively on digital infrastructure fail to achieve long-term sustainability unless they are supported by strong institutional capacity and structured mechanisms for citizen participation, confirming that engagement plays a decisive role in governance effectiveness. Empirical research on social media use in urban planning further shows that digital platforms substantially enhance public involvement by lowering participation barriers and enabling more frequent two-way interaction between citizens and local authorities (Ouyang et al., 2025). In addition, studies of citizen engagement strategies in smart cities indicate that hybrid participation models combining digital tools with offline access significantly broaden inclusivity and mitigate digital divide effects, particularly among socially and digitally vulnerable groups (Hansen & Dahiya, 2025). These findings suggest that meaningful citizen participation represents a foundational element of smart city governance rather than a secondary outcome of technological advancement.

Smart city development is increasingly associated with digital transformation strategies in public administration and innovations in public service delivery. Key elements of development include digital connectivity (e.g., 5G networks, Wi-Fi coverage), smart transportation systems, energy efficiency, and the collection of urban data through sensors (Nam & Pardo, 2011; Caragliu et al., 2011). However, many authors emphasize that technological solutions alone do not guarantee successful development unless combined with a social dimension, including citizen participation and inclusive policy (Hollands, 2015; Mora et al., 2019). In developing countries such as Serbia, the challenges of smart city development include limited institutional capacity, constrained budgets, fragmented digitalization strategies, and low levels of digital literacy (Tan & Taeihagh, 2020). Nevertheless, Belgrade and Novi Sad demonstrate potential through digital infrastructure and e-governance projects, while Kragujevac and Niš invest in smart transportation systems and energy-efficient public lighting (Simić & Popović, 2021). Although smart urban development trends are present in Serbia, the full transformation toward a genuinely functional smart city requires integration of existing partial solutions, expansion of development indicators, attention to social dimensions, and the application of open data to increase transparency and public trust (Stojkov Pavlović, 2023). In general, successful smart city development requires a multisectoral approach, integrating technology with societal needs and a long-term strategy.

In recent years, smart city development has become increasingly reliant on digital citizen participation as a key factor in the success of smart urban policies and technologies. In the literature, smart cities are defined as socio-technical systems in which technology and society interact, with active citizen participation being essential to their sustainability (Margherita et al., 2021). In this sense, citizens should not only be users but also co-creators of urban solutions. Digital participation most commonly occurs via social networks, e-portals, mobile applications, forums, and online petitions, enabling citizens to directly influence the shaping of public policies and services (Bastos et al., 2022; Obradović et al., 2025). According to Tan & Taeihagh (2020), in developing countries such as Serbia, the success of smart city initiatives depends largely on institutional support and the willingness of authorities to include citizens in decision-making processes.

Recent conceptual and empirical research highlights that citizens are not merely passive recipients of smart city services but play an active role in shaping governance processes. Conceptual work on smartwashing suggests

that smart city imaginaries can sometimes mask superficial participation when digital tools are employed more for legitimacy than for genuine influence (Loe et al., 2024). In contrast, empirical research on actual practices of citizen participation shows that inclusive and rights-based engagement strategies can strengthen the role of citizens in smart city development and help ensure that participation is equitable and meaningful rather than tokenistic (Kumar, 2024). Case study on citizen engagement in smart city platforms demonstrates that active participation significantly contributes to project success by enabling more comprehensive urban problem identification and collaborative problem-solving (Hansen & Dahiya, 2025). These studies suggest that digital governance approaches should be designed to enable substantive participation and that hybrid mechanisms combining digital and offline engagement may be most effective in fostering citizen influence and improving.

One of the modern theoretical approaches is the concept of the "right to the smart city," which asserts that citizens have the right to participate in the digital transformation of their communities not only through passive use of services but also through active co-production of policies (Leclercq & Rijshouwer, 2022). Despite substantial technological opportunities, many local governments in Serbia still use social networks and applications primarily for information dissemination, rather than for interactive communication with citizens, which limits the scope of participation (Fehér, 2020).

Effective operationalization of the smart city concept in Serbia requires clearly defined indicators adapted to the local context, with key areas of development including smart economy, smart governance, and urban mobility (Vasilic, 2018). The use of advanced methodological approaches, such as interval type-2 fuzzy models, enables a more precise understanding of the complexity of smart city development, as these approaches integrate subjective and objective data and recognize domains such as governance, citizens, and the environment as strategically significant (Milinković et al., 2019). Research conducted in Novi Sad, in the context of its status as the European Capital of Culture, highlights a growing need for smart solutions tailored to increasingly complex urban demands, with an emphasis on citizen inclusion, infrastructure transformation, and the use of digital technologies in creating cultural and social content (Bolesnikov et al., 2024). Although smart cities in Serbia are still in the early stages of implementation, these findings confirm the existence of real potential for further development through strategic management, integration of modern technologies, and a participatory approach involving citizens (Vasilic, 2018; Milinković et al., 2019; Bolesnikov et al., 2024).

3. Methodology

The main objective of this research was to investigate the relationship between digital citizen participation and smart city development, as well as to identify differences in these dimensions among respondents from the five largest urban centers in Serbia. The study included 332 participants and was conducted via an online survey from March to June 2025, targeting residents of Belgrade, Novi Sad, Niš, Kragujevac, and Subotica.

The questionnaire was structured in two sections. The first part gathered demographic data such as gender, age, education level, employment sector, and city of residence. The second part comprised ten sets of questions, each corresponding to a specific dimension of Digital Citizen Participation or Smart City Development. Each variable was represented by three statements, and respondents rated their agreement on a five-point Likert scale (from 1 - strongly disagree to 5 - strongly agree). All statements were formulated to accurately capture essential aspects of digital communication, engagement, service use, and perceptions of urban innovation.

Digital citizen participation was analyzed through five variables. The variable Social Networks assessed the degree to which respondents follow official city pages, actively comment on and like posts regarding city issues, and perceive social media as a vital channel for communicating with local authorities. The variable E-Portals measured how often respondents use city web portals for local information, their perception of the portals' usefulness, and ease of accessing information relevant to everyday life. The variable Forums described involvement in local online discussions, the value of forums for exchanging opinions on city topics, and the contribution of these discussions to improved citizen participation. The variable Mobile Applications evaluated the frequency of using city apps for problem reporting, public transport, or accessing urban information, as well as their efficiency and impact on citizen involvement. The variable Online Petitions captured the experience of signing digital petitions related to local issues, perceptions of their effectiveness, and the belief that local authorities consider the results.

As for the dimensions of smart city development, the variable Digital Infrastructure measured perceptions of Wi-Fi coverage, the use of smart devices, and the implementation of sensors and technology to enhance urban services and daily life. The variable Smart Governance assessed the availability of electronic services, the development and functionality of city e-government, and the degree to which digital services save time and increase efficiency. The variable Sustainability referred to the city's investment in environmental protection through smart solutions, the existence of recycling and energy-saving systems, and whether sustainability is recognized as a policy priority. The variable Innovative Services evaluated the adoption of new technologies in public transport, healthcare, or education, as well as the perceived benefits of services such as smart parking and bike-sharing. The variable Quality of Life examined the extent to which the implementation of smart solutions enhances safety, comfort, overall satisfaction with life in the city, and a sense of community belonging through technological advancement.

Prior to distribution, the questionnaire was pilot-tested on a smaller sample to ensure clarity and reliability, resulting in minor adjustments for improved validity. Participation was voluntary and anonymous, and all collected data were used solely for research purposes.

The formulation of the research hypotheses is grounded in contemporary literature on smart cities and digital governance that recognizes digital citizen participation as an important determinant of smart urban development. Empirical studies demonstrate that the use of digital participation tools contributes to more effective identification of urban problems, improved interaction between citizens and local authorities, and better alignment of public services with citizens' needs (Kumar, 2024; (Hansen & Dahiya, 2025). At the same time, conceptual research cautions that the mere presence of digital "smart" solutions does not guarantee meaningful participation, as participatory tools may sometimes serve symbolic rather than substantive governance functions, a phenomenon described as smartwashing (Loe et al., 2024). These findings provide a clear theoretical justification for examining the relationships between different forms of digital citizen participation and key dimensions of smart city development through a structured questionnaire-based empirical approach.

Based on prior theoretical and empirical findings, two research hypotheses were tested:

- H1: Variables of digital citizen participation show statistically significant relationships with smart city development variables.
- H2: There are significant differences in digital participation and smart city development across identified clusters of respondents.

Data analysis was conducted using SPSS 25. The methodology included descriptive statistics, correlation analysis to examine relationships between variables, regression analysis to evaluate the influence of digital participation dimensions on smart city development, K-means cluster analysis to group respondents by response patterns, and one-way ANOVA to test differences between clusters. Measurement reliability was assessed with Cronbach's Alpha coefficient.

4. Result and discussion

A detailed demographic breakdown of the research sample is presented in Table 1, providing insight into the structure of respondents by city, gender, age group, education level, and employment sector. This diversity and balance within the sample ensure the reliability of subsequent analyses related to digital citizen participation and smart city development in Serbia.

Table 1. Demographic Structure of Respondents

Variable	Category	Frequency	Percentage (%)
City	Beograd	101	30.4
	Novi Sad	86	25.9
	Niš	79	23.8
	Kragujevac	29	8.7
	Subotica	37	11.1
Gender	Male	172	51.8
	Female	160	48.2
Age group	Up to 25	39	11.7
	26-60	253	76.2
	Over 60	40	12.1
Education	Primary education	21	6.3
	Secondary education	119	35.8
	Higher education	71	21.4
	University degree	121	36.4
Employment	Public	131	39.5
	Private	201	60.5

Source: Author's calculation based on SPSS 25

The demographic analysis demonstrates that the sample includes respondents from all major urban centers in Serbia, with Belgrade and Novi Sad being most represented. The gender distribution is balanced, while the largest proportion of participants is within the active working-age group (26-60 years). The sample covers a broad educational spectrum, with a notable presence of respondents holding secondary and university degrees. Finally, the employment sector data reveal a higher share of individuals working in the private sector, supporting the relevance and applicability of the results to various urban contexts.

For a better understanding of citizens' attitudes towards digital participation and smart city development, a descriptive statistical analysis was conducted for ten key variables encompassing various aspects of digital communication, infrastructure, and sustainable urban development. The analysis was carried out on a sample of 332 respondents. The results of the descriptive statistics are presented in Table 2.

Table 2. Descriptive statistics of variables: digital participation and smart city development

Variable	Mark	N	Min	Max	Mean	Std. Deviation	Cronbach's Alpha
Social Networks	DCP1	332	1	5	3.63	0.991	0.732
E-Portals	DCP2	332	1	5	3.60	0.946	0.754
Forums	DCP3	332	1	5	3.03	0.934	0.817
Mobile Applications	DCP4	332	1	5	3.44	1.049	0.782
Online Petitions	DCP5	332	1	5	2.55	0.873	0.735
Digital Infrastructure	SCD1	332	1	5	3.66	1.014	0.844
Smart Governance	SCD2	332	1	5	3.62	1.091	0.915
Sustainability	SCD3	332	1	5	3.54	1.005	0.834
Innovative Services	SCD4	332	1	5	3.39	0.969	0.795
Quality of Life	SCD5	332	1	5	3.64	0.971	0.811

Source: Author's calculation based on SPSS 25.

The results indicate that respondents rated digital infrastructure (M = 3,66; SD = 1,014), quality of life (M = 3,64; SD = 0,971), and social networks (M = 3,63; SD = 0,991) most positively, suggesting that citizens recognize the value of a technologically advanced urban environment, including access to information and digital services. On the other hand, online petitions received the lowest average score (M = 2,55; SD = 0,873), which may reflect insufficient citizen engagement in formal forms of digital participation or skepticism regarding their effectiveness.

The smart governance variable exhibited the highest reliability (α = 0,915), indicating that its constituent items are highly coherent and relevant for assessing e-governance in cities. All variables achieved a Cronbach's Alpha above the recommended threshold of 0,70, demonstrating high internal consistency and reliability of the measurement instruments. The lowest, yet still satisfactory, value was recorded for the social networks variable (α = 0,732), while the average standard deviation is moderate, indicating a solid dispersion of attitudes among respondents and confirming the validity of the obtained results.

Considering the identified trends, it can be concluded that citizens in Serbia generally rate most digital aspects of urban life positively, with particular emphasis on infrastructure and access to information, while remaining more skeptical toward channels that require a higher level of engagement, such as online petitions and forums. This represents a significant basis for further development of smart governance policies aimed at participation and transparency.

Correlation analysis was applied to examine the strength and direction of the relationship between variables related to digital citizen participation (DCP) and smart city development (SCD). The goal of this analysis is to identify to what extent the use of digital tools by citizens (such as social media, e-portals, forums, mobile applications, and online petitions) is associated with various dimensions of smart city advancement (digital infrastructure, smart governance, sustainability, innovative services, and quality of life). Pearson's correlation coefficients were calculated, and the results are presented in the table 3.

Table 3. Correlation coefficients between digital citizen participation and smart city development variables

	DCP1	DCP2	DCP3	DCP4	DCP
SCD1	0.581**	0.442**	0.312**	0.474**	0.407**
SCD2	0.597**	0.463**	0.389**	0.504**	0.360**
SCD3	0.483**	0.536**	0.486**	0.531**	0.347**
SCD4	0.460**	0.452**	0.353**	0.487**	0.382**
SCD5	0.476**	0.547**	0.386**	0.490**	0.414**

Note: Correlation is significant at the 0.01 level (2-tailed)

Source: Author's calculation based on SPSS 25

The results of the correlation analysis indicate that all variables of digital citizen participation are statistically significant and positively associated with the indicators of smart city development. The strongest correlation was observed between SCD2 (smart governance) and DCP1 (social media), with a value of 0,597, suggesting a strong relationship between the use of social networks and the perception of efficient e-governance. This finding can be interpreted to mean that citizens who actively follow and engage in digital communication with local authorities via social media tend to have greater trust and satisfaction with smart governance services.

High correlation values were also recorded between SCD3 (sustainability) and DCP2 (e-portals) - 0,536, as well as between SCD5 (quality of life) and DCP2 - 0,547, indicating that the quality of e-portals significantly contributes to the perception of sustainability and overall quality of life in urban environments.

On the other hand, the weakest correlations were noted between SCD1 (digital infrastructure) and DCP3 (forums) - 0,312, which may suggest that participation in forums has a limited impact on perceptions of a city's digital infrastructure. Additionally, the overall correlation between the aggregate variable DCP and all SCD indicators ranges from 0,347 to 0,414, pointing to a moderate association between digital participation and smart city development in general.

These findings confirm the validity and functionality of the developed measurement instruments, as all

relationships are statistically significant ($p < 0,01$), and the correlations are consistent and theoretically justified. Such results provide a solid foundation for further modeling of impact using regression analysis. The results of the regression analysis are presented in Table 4.

Table 4. Regression model of the influence of independent variables of digital citizen participation on the dependent variables of smart city development (only statistically significant variables are presented)

Dependent	Independent	β	t	Sig.	R^2	F	Sig.
SCD1	DCP1	.391	7.961	.000	.438	50.826	.000
	DCP4	.167	2.985	.003			
	DCP5	.186	4.095	.000			
SCD2	DCP1	.397	8.236	.000	.458	55.019	.000
	DCP4	.167	3.035	.003			
SCD3	DCP1	.199	4.111	.000	.454	54.216	.000
	DCP2	.253	4.914	.000			
	DCP3	.216	4.473	.000			
	DCP4	.162	2.929	.004			
SCD4	DCP1	.215	4.123	.000	.366	37.560	.000
	DCP2	.167	3.016	.003			
	DCP4	.209	3.512	.001			
	DCP5	.176	3.648	.000			
SCD5	DCP1	.200	4.059	.000	.435	50.111	.000
	DCP2	.303	5.784	.000			
	DCP5	.190	4.170	.000			

Source: Author's calculation based on SPSS 25

In the conducted regression analysis, the relationship and predictive power of independent variables related to digital citizen participation were examined in relation to the dependent variables representing key dimensions of smart city development. Only those variables that demonstrated a statistically significant contribution to the prediction of dependent variables (at a significance level of $p < 0,01$) were included in the analysis, with results presented through standardized regression coefficients (β), t-values, significance levels (p), as well as the coefficient of determination (R^2) and F-test values for each model.

The dimension of digital infrastructure demonstrates a high degree of dependence on several forms of digital participation. The greatest impact is observed for the use of social networks ($\beta = 0,391$; $t = 7,961$; $p < 0,001$), while mobile applications ($\beta = 0,167$; $t = 2,985$; $p = 0,003$) and online petitions ($\beta = 0,186$; $t = 4,095$; $p < 0,001$) also make statistically significant contributions. The total variance explained by the model amounts to 43,8% ($R^2 = 0,438$), indicating a substantial contribution of these digital tools in shaping perceptions of the presence and quality of digital infrastructure in urban environments.

Regarding the development of smart governance, the results indicate that the most influential predictors are again social networks ($\beta = 0,397$; $t = 8,236$; $p < 0,001$) and mobile applications ($\beta = 0,167$; $t = 3,035$; $p = 0,003$). This model achieves the highest coefficient of determination in the analysis ($R^2 = 0,458$), meaning that nearly half of the variance in the assessment of smart governance development can be explained by digital engagement of citizens. This finding confirms the importance of direct interaction with institutions through digital channels in enhancing the transparency and accessibility of local government. Sustainability, as the third observed dimension, exhibits a strong association with multiple aspects of digital participation: social networks (β = 0,199), e-portals (β = 0,253), forums (β = 0,216), and mobile applications (β = 0,162), all with significance levels below $p < 0,01$. The overall R^2 for this model is 0,454, indicating pronounced predictive power. The significant impact of e-portals and forums suggests that information exchange and public discussion contribute to collective awareness and citizen engagement in ecological and sustainable initiatives in their city. The dimension of innovative services is significantly predicted by four forms of digital participation: social networks ($\beta = 0,215$), e-portals ($\beta = 0,167$), mobile applications ($\beta = 0,209$), and online petitions (β = 0,176). Although the R^2 for this model is somewhat lower (0,366), it still indicates a moderate relationship between the use of digital services and the perception of innovations in areas such as smart transportation, healthcare, or education. Quality of life as a dimension of the smart city depends on the following predictors: social networks (β = 0,200), e-portals (β = 0,303), and online petitions ($\beta = 0,190$), with an overall $R^2 = 0,435$. The particular influence of e-portals stands out, implying that citizens who use local digital platforms report a higher level of subjective assessment regarding their living standards, safety, and comfort.

The results of the regression analysis demonstrate that digital citizen participation significantly contributes to the development of all key dimensions of the smart city. The most consistently present and influential variable is DCP1 - the use of social networks, which emerges as a predictor in all five models. In addition, mobile applications (DCP4) and online petitions (DCP5) stand out as channels that enable active citizen involvement and a better perception of digital transformation in cities. These results clearly indicate the need to strengthen digital infrastructure and participation strategies in order to improve quality of life and the efficiency of urban governance.

The coefficient of determination, as an indicator of the overall strength of the model, is highest in the model related to smart governance ($R^2 = 0,458$), indicating that digital citizen participation - particularly through social networks and mobile applications - best explains the perception of e-governance development. This finding suggests that digitally empowered citizens perceive their local administration as more efficient, accessible, and modern, which is a key prerequisite for achieving a functional smart city.

Cluster analysis was applied to a sample of 332 respondents from five Serbian cities using the K-means clustering method, with the goal of identifying distinct groups based on patterns of digital participation and perceptions of smart city development. The analysis identified three significant clusters, which are presented in Table 5. These clusters encapsulate different behavioral and perceptual profiles among respondents regarding their digital engagement and evaluation of smart urban service

Table 5. Cluster profiles by average ratings

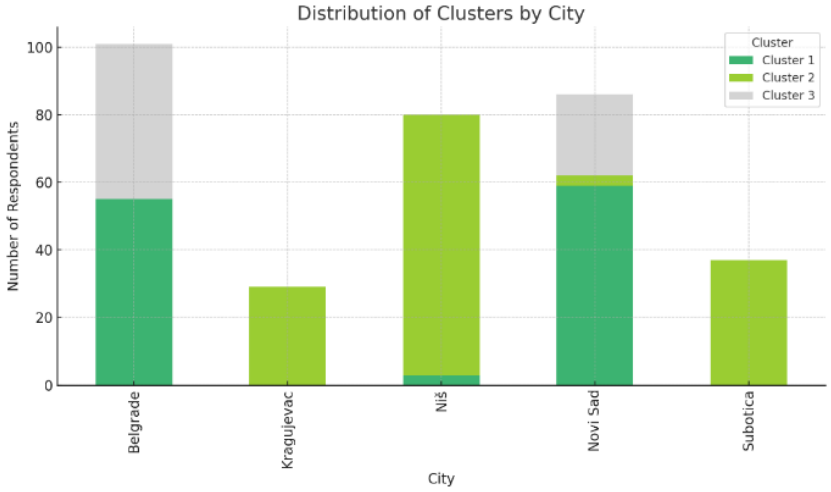
Cluster	Description	Characteristics	Total Respondents	Major Cities
Cluster 1	High participation and development	Respondents give high ratings for digital participation (e.g., DCP1 = 4,40) and smart city development (e.g., SCD1 = 4,39, SCD2 = 4,50); mainly from large urban centers.	116	Belgrade (55) Novi Sad (59)
Cluster 2	Low participation and low development	This cluster has the lowest average scores across most variables (e.g., DCP5 = 2,00, SCD1 = 2,89), indicating low engagement and weak infrastructure.	146	Niš (77) Subotica (37) Kragujevac (29)
Cluster 3	Digitally oriented cities with strong innovation	High ratings for digital services (e.g., DCP2 = 4,44, DCP4 = 4,65) and smart services (SCD3 = 4,58, SCD5 = 4,51); respondents are highly informed and tech-savvy.	70	Belgrade (46) Novi Sad (24)

Source: Author's calculation based on SPSS 25

The table provides a concise overview of the profiles of the identified clusters based on the respondents' average ratings. The first cluster, labeled as "Cluster 1," is characterized by high participation and well-developed smart city features - respondents from this group, primarily from Belgrade and Novi Sad, on average assign the highest scores to both digital participation and smart city components. "Cluster 2" comprises the largest group of respondents with lower average values for almost all variables, indicating weaker citizen engagement and less developed digital infrastructure. This group is dominant in Niš, Subotica, and Kragujevac. The third cluster, "Cluster 3," consists of respondents who demonstrate a strong orientation toward innovation and digital services - they are highly informed, frequently use modern technologies, and are mainly from larger urban centers such as Belgrade and Novi Sad. These profiles provide insight into regional disparities and the level of digital maturity among respondents from different Serbian cities.

The figure 1 representation above illustrates the distribution of the three identified clusters by city. Cluster 1, associated with high digital participation and smart city development, is prominently represented in Belgrade (55 respondents) and Novi Sad (59 respondents), highlighting these cities as leaders in digital integration and civic engagement. Cluster 2, defined by low participation and underdeveloped infrastructure, is dominant in Niš (77 respondents), Kragujevac (29), and Subotica (37), underscoring the digital and infrastructural lag in these locations. Cluster 3, described as digitally oriented cities with a focus on innovation, includes 46 respondents from Belgrade and 24 from Novi Sad, indicating a subgroup of highly digitally literate individuals who emphasize the adoption of innovative technologies and services.

Figire 1. Distribution of respondents across the three identified clusters by city



Source: Author's projection based on research results

These findings suggest notable regional disparities in the adoption of digital tools and services associated with smart cities. The dominance of Cluster 2 in cities such as Niš and Subotica underscores the need for targeted policy interventions to bridge the digital divide and stimulate smart development initiatives. In contrast, Clusters 1 and 3 highlight the potential for Belgrade and Novi Sad to serve as hubs of innovation and models of best practice in digital governance and civic engagement. The detailed results are presented in Table 6.

Table 6. ANOVA results for cluster differences

	DCP1	DCP2	DCP3	DCP4	DCP5	SCD1	SCD2	SCD3	SCD4	SCD5
F	5.99	0.55	18.13	8.88	0.15	7.24	8.99	0.05	1.74	0.33
p-value	0.0028	0.5796	0.00000	0.00018	0.8618	0.0008	0.0001	0.9539	0.1776	0.718

Source: Author's calculation based on SPSS 25

The one-way ANOVA revealed statistically significant differences among the three identified respondent clusters regarding several key variables of digital participation and smart city development. The most pronounced differences were observed for the use of social media (DCP1, $F = 5,99$, $p = 0,0028$), forums (DCP3, $F = 18,13$, $p < 0.001$), and mobile applications (DCP4, $F = 8,88$, $p < 0,001$), as well as for perceptions of digital infrastructure (SCD1, $F = 7,24$, $p < 0.001$) and smart governance (SCD2, $F = 8,99$, $p < 0,001$). Tukey post-hoc tests confirmed that Clusters 1 and 3, primarily composed of respondents from Belgrade and Novi Sad, recorded significantly higher mean scores for these variables compared to Cluster 2, which is characteristic of Niš, Kragujevac, and Subotica.

In contrast, variables such as e-portals, online petitions, innovative services, and quality of life did not demonstrate significant differences across clusters ($p > 0,05$), indicating uniformity in these aspects among all respondents. In summary, the results confirm the existence of a digital divide between leading and peripheral urban centers, with Belgrade and Novi Sad significantly ahead in terms of digital participation and the development of smart city services. This highlights the need for targeted interventions to digitally empower less developed cities.

The obtained findings are largely consistent with recent empirical and conceptual studies on smart city development and digital citizen participation. In line with empirical evidence on participatory smart city practices, the results confirm that digital communication channels, particularly platforms enabling direct interaction between citizens and local authorities, play a significant role in shaping perceptions of governance effectiveness and responsiveness (Kumar, 2024; Hansen, 2025). These findings suggest that citizens who actively engage through digital participation mechanisms tend to evaluate smart governance more positively, as such tools facilitate problem identification, feedback exchange, and more efficient service delivery.

The observed regional disparities between Belgrade and Novi Sad, on the one hand, and cities such as Niš, Kragujevac, and Subotica, on the other, are consistent with studies highlighting uneven patterns of citizen participation and digital capacity across urban contexts. Empirical research indicates that cities with higher levels of institutional readiness and digital engagement infrastructure demonstrate stronger participatory outcomes, while less developed urban areas face structural and organizational constraints that limit meaningful citizen involvement (Kumar, 2024; Hansen, 2025). From a conceptual perspective, these disparities may also reflect the phenomenon of smartwashing, where the formal presence of digital tools does not necessarily translate into substantive participation or governance transformation (Loe et al., 2024).

The research findings clearly demonstrate that both proposed hypotheses have been empirically confirmed. The first hypothesis, which posited that variables of digital citizen participation would exhibit statistically significant relationships with variables of smart city development, was validated through multiple analytical procedures. Results from correlation and regression analyses indicate that dimensions of digital engagement - such as the use of social networks, forums, and mobile applications - exert a significant influence on the perception and development of key aspects of the smart city, including digital infrastructure, smart governance, and sustainability. The highest correlation and regression coefficients were recorded for these connections, highlighting the powerful impact of digital citizen participation on the digital transformation of urban environments.

The second hypothesis, which assumed significant differences in digital participation and smart city development among distinct citizen clusters, was also confirmed. Cluster analysis and one-way ANOVA revealed statistically significant differences among identified respondent groups, with the most advanced digital profiles observed among participants from Belgrade and Novi Sad, while cities such as Niš, Kragujevac, and Subotica lag behind. The most pronounced differences were observed in the use of social networks, mobile applications, and assessments of digital infrastructure and smart governance.

Based on these results, it can be concluded that both research hypotheses have been empirically supported, providing a solid foundation for further recommendations aimed at advancing digital participation and smart urban solutions across Serbia.

5. Conclusion

The conducted study confirmed the pivotal role of digital citizen participation in smart city development, clearly identifying statistically significant relationships between various forms of digital engagement and progress in the areas of digital infrastructure, smart governance, and

innovative urban services. Cluster and ANOVA analyses revealed notable differences among respondents from different cities, evidencing the existence of a digital divide between major urban centers and more peripheral cities. These findings offer a reliable basis for designing targeted public policies and initiatives focused on enhancing digital literacy and infrastructure, particularly in locations that lag behind on digital indicators.

However, the research is subject to certain limitations. First, the sample was limited to five major Serbian cities, which may constrain the generalizability of the results to other urban and rural contexts. Second, the study relied on self-reported data from respondents, which introduces the potential for subjectivity and response bias. Third, the analysis primarily utilized quantitative methods, whereas qualitative approaches (such as interviews and focus groups) could provide deeper insights into the motives and barriers to digital participation.

From a theoretical perspective, this study contributes to the growing body of smart city literature by empirically confirming the central role of digital citizen participation in the context of a developing European country. Unlike many existing studies that focus primarily on technologically advanced Western cities, the findings provide empirical evidence from Serbia and underline the importance of socio-institutional factors in shaping smart city development and governance outcomes. From a practical standpoint, the results offer valuable guidance for policymakers by identifying specific forms of digital participation, particularly social networks and mobile applications, as channels that exert the strongest influence on smart city development and perceived quality of life. These insights may support the design of more inclusive and participatory digital governance strategies and assist local authorities in prioritizing digital tools that foster more effective interaction with citizens and improve urban service delivery.

Future research should be expanded to include a larger number of cities and encompass smaller urban and rural areas in order to capture a comprehensive national perspective on digital transformation. Additionally, a longitudinal approach is recommended to track changes in digital participation and smart city development over time. The integration of qualitative methods, as well as analyses of other factors (such as economic status, age structure, and institutional support), may contribute to a more comprehensive understanding of this complex phenomenon and enable the creation of even more effective strategies for the development of smart and inclusive cities in Serbia.

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