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A study of components predicting smart governance in Prishtina, Kosovo

This research pinpoints key drivers of smart governance in Prishtina, Kosovo, using a quantitative approach. A self-report survey with 1,536 respondents, selected through stratified probability sampling, provided the necessary data. Principal component analysis was applied to assess the questionnaire's internal structure, and regression analysis helped reveal smart governance predictors. Two pivotal findings emerged concerning Prishtina's smart governance. Smart city management and smart collaboration were the most significant determinants, with the former demonstrating a slightly stronger correlation. These results underscore the role of effective city man-

agement practices and stakeholder collaboration in directing governance outcomes in smart cities. In light of this, policymakers are advised to emphasize stakeholder collaboration in smart city initiatives. For Prishtina, this translates into increased cooperation, transparency, accessibility to data in management practices, and a focus on infrastructure and public services to enhance smart city governance.

Keywords: smart city management, smart collaboration, smart governance, Prishtina, Kosovo

1 Introduction

Effective implementation of smart city projects requires strong governance mechanisms that integrate multiple stakeholders (Ruhlandt, 2018). Information and communications technology (ICT) can improve general governance, leading to efficient resource allocation, collaboration, communication of rules and policies, and social innovations, referred to as smart governance (Backus, 2001; O'Reilly, 2011). Smart governance involves the interaction of technologies, people, policies, practices, resources, social norms, and information that foster city governance efforts (Chourabi et al., 2012). It encompasses government-to-citizen (G2C), government-to-business (G2B), and government-to-government (G2G) governance (cf. Bernardo, 2017; Anindra et al., 2018). Smart governance consists of three core components: stakeholder involvement, ICT services, and network-oriented connections, such as collaborations or partnerships (Gil-Garcia et al., 2015).

Components of smart governance encapsulate stakeholder roles and duties, frameworks, and institutions that regulate the interplay and alliances among stakeholders, and procedures associated with sharing information, collaboration, formulating decisions, and execution. In addition, they incorporate technologies and data that facilitate competent governance, along with policy and legislative structures to address challenges related to smart cities (Bolívar & Meijer, 2016; Meijer, 2016; Chelvachandran et al., 2020; El-Ghalayini & Al-Kandari, 2020; Razmjoo et al., 2021). Outcomes of smart governance and their corresponding metrics include wellbeing, social and digital inclusion, amenities delivered, public involvement, funding allocated for smart governance endeavours, economic expansion, and job opportunities (Castelnuovo et al., 2016; Ruhlandt, 2018; Herdiyanti et al., 2019; Alsaïd, 2021). Situational elements such as the level of autonomy enjoyed by smart cities or local circumstances also predict smart governance outcomes and components (Bolívar & Meijer, 2016; Meijer, 2016; Ruhlandt, 2018).

Smart city governance is a collaborative hybrid model involving public administration, the private sector, and citizen participation (Sancino & Ve Hudson, 2020). Rather than purely being a tech-driven initiative, it incorporates strategic use of administrative organizations, governance-oriented policies, and information resources (Nam & Pardo, 2011). ICT-based governance (Chourabi et al., 2012) extends beyond technology, combining social norms and information resources, thereby enhancing city management and streamlining decision-making. Notably, the evolution of smart city governance creates

new dynamics in stakeholder relationships. According to Shelton et al. (2015), data-driven governance projects lead to the formation of extra-regional networks among key actors and institutions, thereby shaping urban futures through targeted plan financing and implementation. Angelidou (2015) further posits that active participation and stakeholder coordination form the bedrock of smart governance. In essence, smart city governance hinges on technological integration, strategic partnerships, and active stakeholder involvement, heralding a shift toward data-driven, citizen-centric urban management.

The use of different dimensions to enhance the city's smart governance system requires strategic prioritization and innovative financing mechanisms to support the development of smart city infrastructure and service improvement, particularly in developing countries with large informal economies. Therefore, the research gap identified involves studying which dimensions of smart governance most significantly affect the implementation of smart governance in an understudied region such as Kosovo. Kosovo, as a developing country, has budgetary restrictions that make it challenging to meet all the city government needs. The findings of this study could help different city government structures in various developing countries that face similar financing and other challenges. They will better understand how to set strategic priorities in enhancing their smart governance system.

Based on the definition of the smart city concept, Prishtina is not considered a smart city in the global context (Nimani, 2014). One of the primary challenges that Prishtina faces in achieving smart governance involves leveraging innovation and technology to efficiently use resources. It also needs to ensure citizen participation through e-participation and e-governance, which are vital for addressing issues and enhancing the quality of life for residents (Ubo Consulting, 2020). Even though 97% of the population has internet access, along with a thriving ICT industry and a young population of millennial entrepreneurs and professionals with a disruptive vision, it remains uncertain whether Prishtina is effectively using these resources to move toward becoming a sustainable and digital city (Musliu, 2021). In light of this, it is crucial to prioritize smart governance, not only for Prishtina but also for other cities in Kosovo, based on smart city indicators to ensure their long-term success (Pallaska, 2020). Consequently, city policymakers need to propose measures to promote smart development.

To fill the research gaps identified in global literature and in a rapidly urbanizing city such as Prishtina, this study identifies the most important predictors of smart governance in Prishtina. This will contribute to the literature in this field, especially by prioritizing the most important dimensions influencing smart governance.

1.1 Literature review

The review of previous research reveals varying perspectives on what constitutes a smart city. Some sources view the smart city as smart governance, whereas others equate the smart city with innovative manners of decision making, innovative management, and innovative forms of cooperation (Meijer & Bolívar, 2016). One form of innovative management in smart developed countries is data-driven decision-making (Ahvenniemi et al., 2017), which requires an integrated approach to management, in which various stakeholders collaborate to achieve common goals (Spence, 2017). This can involve the use of innovative forms of cooperation such as co-creation, co-design, and co-production, which emphasize the involvement of residents and other stakeholders in planning and implementing smart city initiatives (Ahvenniemi et al., 2017).

Smart city management relies on integrating and optimizing infrastructure, including transportation, energy, waste management, and public services. Recent studies suggest several approaches to improving the sustainability and efficiency of urban infrastructure. Liu et al. (2017) proposed an integrated model for transportation, energy, and communication systems. However, implementing smart city infrastructure requires significant resources, and the presence of large informal economies can complicate the realization of smart city ideals (Allam & Dhunny, 2019). A strategic approach that prioritizes innovative financing mechanisms and technology can help address these challenges and facilitate the integration of smart technologies into urban areas. By doing so, governments can create more efficient and sustainable cities, resulting in enhanced quality of life for residents (Caragliu et al., 2011). Access to public services is also a crucial aspect of smart city management. Technology and innovation can improve the city's service delivery (Atthahara, 2018), and stakeholder collaboration, including businesses and community groups, is essential to city transformation (Ziozias & Anthopoulos, 2022). According to Bibri and Krogstie (2020), there has been an emerging trend of data-driven smart city management by employing innovative solutions in Barcelona, including artificial intelligence (Rijab & Melloulli, 2018). There have been improvements in smart city management, especially with respect to the digitalization of public transportation in Barcelona through electronic ticket booking and validation self-service (Chiscano & Darcy, 2022), and a unified ticketing system (Smith & Martin, 2021). Overall, community engagement is crucial to achieving effective strategic planning and successful city transformation.

City managers should pay attention to residents' and stakeholders' concerns and include them in governance (Lopes 2017; Vrabie & Tirziu, 2021). Data accessibility through digitalization of towns can be used to improve decision-making

and cities' e-governance (Deakin & Waer, 2011). Data transparency about decision-making helps cities achieve more legitimacy in the public eye (de Fine Licht & de Fine Licht, 2020). Data accessibility, decision-making transparency, and citizen participation in information about city decisions enhances a city's governance and decision-making structure (Jurado-Zambrano et al., 2023). Transparency creates greater trust and, as a consequence, makes possible clearer decision-making within city structures (Jacobs et al., 2022). In turn, data accessibility helps individuals and communities engage more in decision-making within a city with respect to issues that concern their lives. Data accessibility not only increases transparency and trust in the public eye but also leads to smart initiatives by residents, which overall enhances a city's decision-making and governance system. Data accessibility also has great potential to nurture digital culture among residents and a city's governance structures (Kalarachchi, 2022). ICT-enabled systems create possibilities for individuals and businesses to be better informed about city decisions (Demirel & Mülazımoğlu, 2022).

In young democracies, smart city governance enhances residents' life quality through data-driven policymaking, partnerships, and citizen participation, as suggested by Pereira et al. (2018). This approach, underscored by the principles of collaborative governance (Angelidou, 2015; Grossi et al., 2020), focuses on infrastructural upgrades, IT literacy enhancement, and addressing socio-economic disparities, which are key to the development of a young democracy such as Kosovo (Dzihic, 2019; Domagala, 2020; Mustafa, 2020). This young democracy strongly emphasizes the involvement of residents in decision-making (Lombardi et al., 2012; Bifulco et al., 2017), facilitated by tools such as the e-Kosova platform (E-Kosova Platform, 2023) for smart governance. Furthermore, trust, better coordination, security, and transparency are fostered through multi-stakeholder collaboration (Parenti et al., 2022), a vital aspect considering Kosovo's conflict history (Pallaska, 2020). The transition to collaborative governance harnesses Kosovo's unique strengths, including its youthful population and burgeoning tech sector (Angelidou, 2015), fuelling an inclusive, resilient, and sustainable urban future (Domagala, 2020; UNDP Kosovo, 2023).

Smart collaboration allows the participation of various stakeholders in decision-making, facilitating collaboration and transforming the way cities are managed (Oschinsky et al., 2022). Citizen input is essential in city decision-making, and e-participation is an effective way to achieve a user/citizen-centric approach to smart governance (Lim & Yigitcanlar, 2022). The involvement of residents leads to both smart city initiatives and their better implementation, enhancing the effectiveness of multiple stakeholder collaboration (Bastos et al., 2022; Parenti et al., 2022). Effective collaboration between

stakeholders is crucial to building trust, ensuring better coordination, upholding security, and promoting transparency among parties involved in the implementation of smart city initiatives (Parenti et al., 2022). By ensuring the participation of various stakeholders in planning and decision-making, governance mechanisms become critical to smart city governance (Ruhlandt, 2018).

Smart governance, also referred to as e-governance or e-democracy, involves using modern communication channels to engage residents in decision-making. This concept places emphasis on the transparency of administrative systems and the availability of public services to facilitate citizen participation (Lombardi et al., 2012; Vanolo, 2014). The level of smart governance in the city is measured by the principles of transparency, cooperation, participation, and partnership, including city government accountability, which in turn positively affects residents' quality of life (Demirel & Mülazımoğlu, 2022). Public trust in city decisions allows better and clearer decision-making, consequently affecting city governance. Transparency fosters greater trust and, as a consequence, allows more precise decision-making for city structures (Jacobs et al., 2022). The responsiveness of local government reduces residents' concerns and enhances the value of citizen input (Guo et al., 2022). The city government's responsiveness to residents' concerns heightens residents' perception of local government effectiveness, contributing to smart governance (Wolf et al., 2020).

Based on a thorough literature review, this study addressed the following research question: Which components predict smart governance in Prishtina?

2 Methodology

The study adopts a quantitative research methodology, specifically using the correlational research method to investigate the statistical measure of relationships between variables. This method was chosen due to its ability to provide information about the strength and direction of a relation between two variables, as argued by Burns and Grove (2005) and Leedy and Omrod (2010). Principal component analysis is employed to account for the highest proportion of overall variance (not just common variance) within a correlation matrix by transforming the original variables into a set of linear components (Field, 2017). In this case, items are grouped into components based on their loadings or correlations with each other. This study used multiple regression to examine the predictors of smart governance.

2.1 Research design

This study uses a two-section questionnaire, as suggested by Grum and Temeljotov Salaj (2011). The first section of the questionnaire is composed of three questions aimed at gathering demographic information on sex, age, and education status. The second section contains twelve items related to the study variables, including smart city management, smart decision-making, smart collaboration, and smart governance, with each response on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). The questionnaire was composed of questions related to the following items: 1) access to city infrastructure (transportation, energy, and waste management), 2) access to public services (healthcare, education, and public safety), 3) technology use in service improvement of the city, 4) decision-making transparency, 5) data accessibility, 6) information about city decisions, 7) contribution of residents to city decision-making, 8) stakeholder collaboration with city government, 9) effectiveness of city government in addressing multiple stakeholder concerns, 10) accountability of city government, 11) public trust in city decisions, and 12) city response to residents' concerns and needs.

The study used stratified random sampling to select participants, ensuring the representativeness of Prishtina's population in the study sample, as suggested by Jonker and Penink (2010). The sample comprises 1,536 respondents from Prishtina. The stratification of respondents based on sex, age, education, employment, and job type was conducted in a proportional manner based on the data on sex, age, and education from the 2011 census for Prishtina. A sample of 1,807 participants was randomly selected through Facebook, designed to mirror the proportional stratification, as shown in Table 1. The response rate was 85%, or 1,536 respondents.

Table 1 shows the distribution of respondents according to their sex, age, and education. The strata used in this study are identical to the population strata of Kosovo for the 18 to 65 age group per the latest census (Kosovo Agency of Statistics, 2011).

The age groups from 18 to 65 represent 67% of the total population of Prishtina. The population from 0 to 18 and from 65 to 85 was excluded from the sample. In terms of education status, the active population belonging to the age group from 18 to 65 was taken into consideration for calculating the number of respondents in each stratum.

Given that the total population of Prishtina belonging to the age groups from 18 to 65 is 133,909 (Kosovo Agency of Statistics, 2011), the sample size of 1,536 respondents achieves a margin of error of 2.44%, which is an acceptable level of margin of error in the social sciences, which ranges from 3% to 7%, as suggested by Cochran (1977).

Table 1: Respondent structure.

Respondent type/category	Respondents		Prishtina population, 18–65	
	n	%	n	%
Prishtina	1,536	100.00	133,909	100.00
Sex				
Male	766	49.90	66,821	49.90
Female	770	50.10	67,088	50.10
Total	1,536	100.00	133,909	100.00
Age				
18 to 35	722	47.00	62,893	47.00
36 to 55	583	38.00	51,127	38.00
56 to 65	231	15.00	19,889	15.00
Total	1,536	100.00	133,909	100.00
Education				
Primary school	291	19.00	24,792	19.00
Secondary school	614	40.00	54,682	40.00
Bachelor's degree	552	36.00	48,004	36.00
Master's or doctoral degree	79	5.00	6,431	5.00
Total	1,536	100.00	133,909	100.00

2.2 Research procedure

The questionnaire was distributed to respondents via email through a Google Forms link. An introduction of the study and instructions were included in the form to ensure clarity. The authors selected a web-based survey due to its potential global reach, convenience, flexibility, and ease of data entry, as suggested by Evans and Mathur (2005), who argue that one of the significant strengths of online survey research is that lack of representativeness is no longer an issue because most societies now have internet access and are internet-savvy. Given the high internet penetration rate in Kosovo of 96% (Kosovo ICT Association, 2019), the web-based survey did not impinge on the credibility of the research instrument. The web-based survey was distributed through Facebook, bearing in mind that the number of Facebook users in Kosovo is 932,000 (Digital Kosovo, 2023), and in Prishtina the number of Facebook users is 170,000 (Hallakate, 2020), representing 86% of the total population of Prishtina.

2.3 Statistical analysis

The study used IBM SPSS 23.0 to analyse the quantitative study model to answer the research question. The study employed principal component analysis to explore the internal structure of the questionnaire and the emerging components from a set of items. Principal component analysis (PCA) was used as the initial extraction method. After the initial extraction of components, the study used the oblique rotation meth-

od (promax), assuming that the components were correlated. Rotation was employed to achieve a simpler and more interpretable component structure. Finally, the study used multiple regression analysis to examine the relationship between independent and dependent variables.

3 Results

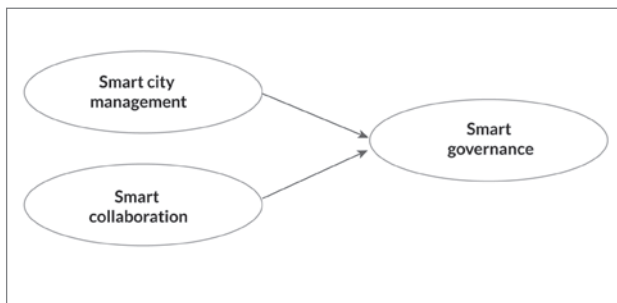
To begin the quantitative study, a reliability analysis was conducted in IBM SPSS 23.0 to evaluate the consistency of twelve variables related to smart city management, smart decision-making, smart collaboration, and smart governance. First, a sampling adequacy test and the Bartlett sphericity test were performed. The KMO measure of 0.835 demonstrates that the chosen sample is sufficient. Bastič (2006) suggests that, for the sample to be adequately representative, the KMO value should exceed 0.5. The sphericity test score of 3927.751 points to a highly significant presence of dimensions that predict the perception of respondents in Prishtina with respect to smart governance. From an inter-item correlation matrix,^[1] it became evident that the inter-item correlations were solid, and so the study could not exclude any of the items from the model, as suggested by Field (2017).

Further, an initial analysis was conducted to secure eigenvalues for every component within the data set. Three components surpassed Kaiser's criterion of 1 as suggested by Field (2017), and in combination accounted for 51.53% of the variance. Further, the study retained three components because of the large

Table 2: Component loadings of the smart city governance questionnaire.

	Component		
	1	2	3
Access to city infrastructure (transportation, energy, waste management)	.619	.028	-.073
Access to public services (healthcare, education, public safety)	.831	-.038	-.199
Technology use in service improvement	.708	-.224	.144
City decision-making transparency	.500	.198	.201
Data accessibility	.483	.310	.029
Information about city decisions	.228	.482	.118
Contribution to city decision-making	-.063	-.041	.679
Stakeholder cooperation with city government (businesses, community groups, interest groups)	.086	-.086	.766
Effectiveness of addressing multiple stakeholder concerns	-.050	-.022	.777
City government accountability	-.161	.447	.414
Public trust in city decisions	-.065	.901	-.109
City response to residents' concerns and needs	-.047	.804	-.073

Note: Extraction method = principal component analysis; rotation method = promax with Kaiser normalization,

**Figure 1:** Hypothesized smart city governance model (illustration: authors).

sample size and the convergence of the scree plot and Kaiser's criterion on this value. Because the questions measure different aspects of smart city management, decision-making, collaboration, and governance, there could be an overlap or correlation between items. Therefore, an oblique rotation (promax) was used to extract component loadings. The rotated component loadings are shown in Table 2.

The items that load onto the same components use the criterion of component loadings of higher than 0.5, as suggested by Field (2017). Hence it is possible to establish the following three components:

- Component 1: Smart city management measured by the following five items: access to city infrastructure, access to public services, technology use in service improvement, transparency, and data accessibility,
- Component 2: Smart governance measured by the following four items: information about city decisions, city government accountability, public trust in city decisions, and the city's response to residents' needs and concerns;

- Component 3: Smart collaboration measured by the following three items: residents' contribution to city decision-making, stakeholder cooperation, and effectiveness of addressing the concerns of multiple stakeholders;

From the loaded items and established components, the design shown in Figure 1 can be established.

Components are often more reliable measures of complex phenomena compared to individual questions. To ensure reliability, Cronbach's alpha was calculated for three components in quantitative research (component one = 0.84, component two = 0.85, component three = 0.78). The results showed that all three components had values greater than 0.69, as recommended by Nunnally (1978). Given the high values, the study used linear regression with components one and three as independent variables and component two as the dependent variable.

Next, multiple regression analysis was used to predict smart governance as a dependent variable. The regression results indicate that the value of R^2 is 0.346, which indicates that 34.6% of smart governance is accounted for by component one (smart city management) and component three (smart collaboration), whereas the remaining amount ($1 - R^2$, or 65.4%) is explained by other dimensions that were not incorporated into the regression model. The regression results indicate that the components of smart city management and smart collaboration explain a significant amount of variance of smart governance with the following values ($F(2, 1532) = 405.91, p < 0.001, R^2 = 0.59, R^2_{adj} = 0.35$).

Table 3: Linear regression coefficients.

Model	Unstandardized coefficients		Standardized coefficients: beta	95% confidence interval for B	
	B	SE		Lower bound	Upper bound
(Constant)	1.005	.084		.841	1.169
Smart city management	.375*	.023	.365	.330	.419
Smart collaboration*	.332*	.021	.350	.291	.374

* $p < 0.001$

Finally, the regression coefficients are presented in Table 3, which indicate that both independent components have significant positive correlations with the dependent component. The standardized coefficients indicate that smart city management has a slightly stronger correlation with smart governance than smart collaboration.

4 Discussion

The findings of the study indicate that both smart city management and smart collaboration have a strong correlation with smart governance. Nevertheless, smart city management seems to have a slightly stronger correlation with smart governance than smart collaboration. The findings show that smart city management is the strongest predictor of smart governance in Prishtina. This is in line with previous research showing a strong relationship between the two components. Bakici et al. (2013) argue that smart city-management practices can enhance governance efficacy and effectiveness. This finding underscores the importance of investing in smart city management practices and offers a promising path for cities to elevate governance quality standards, encourage active involvement of residents, and bolster sustainability.

With respect to practical implications, city authorities and decision-makers should focus their efforts on financing technologies and adopting strategies that allow for effective control of city infrastructure and services while underscoring transparency, accountability, and residents' involvement to drive effective smart city governance. Moreover, future research could explore the specific instruments through which smart city management affects smart governance, as well as investigate the possible moderating effects of contextual elements on this relationship. Nonetheless, funding city-management initiatives such as access to city infrastructure, access to public services, technology use in service improvement, transparency, and data accessibility has significant financial implications for Prishtina as the capital of a developing country. This could represent a challenge for the city government and policymakers, who may need to strike a balance during prioritization between contending demands for limited resources. In addition, transparency

and accountability in making these investments are another challenge. The focus on transparency and resident involvement indicates a necessity for open communication and collaboration between the government and residents to ensure that these investments are aligned with the city's best interests.

Smart collaboration is also a strong predictor of smart governance in Prishtina. The strong relationship between smart collaboration and smart governance has relevance for both theory and practice. This finding offers an understanding of the components that are essential for successfully implementing smart city initiatives in this region. Furthermore, this finding can be informative for policymakers in enhancing smart city governance in Prishtina. Collaboration is an essential component of effective smart governance, as argued by various scholars (Marsal-Llacuna, 2016; Bifulco et al., 2017; Ruhlandt, 2018). Stakeholder collaboration, including collaboration between residents, businesses, and government, plays a pivotal role in the successful implementation of smart city initiatives and projects (Caragliu et al., 2011; Lombardi et al., 2012). Various scholars such as Nam and Pardo (2011), Bifulco et al. (2017), and Lombardi et al. (2012) underscore the vital role that stakeholder collaboration has in creating and promoting smart city initiatives. This finding has relevance for both research and society. First, the finding adds relevance to the smart city governance literature. Second, it also offers a foundation for future research on successful collaboration. Finally, these research findings can guide city managers and policymakers in prioritizing collaboration for ensuring effective implementation of smart city initiatives. This insight can also be used to develop training programs and resources to enhance smart city collaboration, which can ultimately improve the implementation of smart city governance initiatives in Prishtina and elsewhere. However, there are various challenges that may arise during the implementation of such collaboration in a developing country like Kosovo. For example, building trust and cooperation among various stakeholders, especially in a context where residents' trust in government institutions is low, may be challenging. Furthermore, ensuring effective communication among stakeholders that may have different interests, goals, and expectations may also present a

challenge. It is therefore essential for policymakers to consider these challenges and develop strategies to overcome them when promoting collaboration in smart city governance.

Based on the findings discussed above, the strategic implication for Prishtina would be to prioritize smart collaboration and smart city management practices in efforts toward smart city governance. The fact that these two components are the strongest predictors of smart governance suggests that Prishtina should focus on improving collaboration among stakeholders and developing transparent, data-accessible, and technology-driven smart city management practices focused on the improvement of infrastructure and public services. Policymakers, practitioners, and researchers in Prishtina should work toward improving collaboration and city management as a means of achieving more effective and efficient smart city governance.

5 Conclusion

The findings of this study can provide guidance to policymakers in prioritizing collaboration among stakeholders and implementing transparent, tech-driven smart city management in Prishtina, particularly with a focus on infrastructure and public services, aiming for more efficient governance. This study introduces a novel focus on smart collaboration as a key predictor of smart governance, making a significant contribution to smart city governance literature. It suggests that enhancing decision-making can foster better governance outcomes in smart cities and underscores the role of smart city management practices, particularly in developing contexts like Kosovo.

However, there are limitations to the study's correlation-based methodology, which precludes drawing cause-and-effect conclusions. The data, which are self-reported and derived from a single instrument, may suffer from bias and measurement errors. The findings, based on a potentially non-representative sample, may not apply universally, but rather primarily to contexts similar to Prishtina. Future research avenues include understanding the influence of smart city management practices on governance, identifying effective collaboration barriers, and evaluating the cost-effectiveness of various strategies and technologies. These avenues can provide more insight into management strategies, building trust and cooperation, and communication strategies amid conflicting interests. The findings reflect the democratic state of Kosovo, where residents' expectations mirror developed societies, but institutional trust is weaker due to centralized decision-making. Consequently, collaboration emerges as the most viable solution for cities like Prishtina.

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Notes

^[1] The inter-item correlation matrix is available to readers upon request as supplementary material.

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