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The Drivers of Adoption of Smart City Technologies. Insights from the Grand Tunis Metropolitan Area

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Abstract:

The quest for urban sustainability becomes imperative with an increasing global population gravitating towards urban areas. Urban sustainability seeks to harmonize environmental preservation, economic development, and social equity within cities to foster healthy, livable, and resource-efficient environments. Central to this endeavor is the role of urban innovation, particularly Information and Communication Technologies (ICTs), in shaping the vision of smart and sustainable cities. However, while smart cities gain traction worldwide, their development in Africa remains nascent. Based on a survey-based approach, this paper investigates the factors influencing citizen adoption of smart city technologies, focusing on the Grand Tunis Metropolitan area. Leveraging the Technology Acceptance Model (TAM), the study explores factors including trust in technology, perceived ease of use, usefulness, security, and privacy in shaping citizens' behavioral intention toward smart city technologies, which are crucial for their practical and sustainable implementation. The finding put forth the significance of perceived ease of use and trust in technology that shapes residents behavioral intention to use smart city technology and services.

Keywords: Smart cities, Trust in technology, perceived ease of use, usefulness, security, privacy, attitudes, and behavioral intentions.

Introduction

In recent years, there has been an increasing focus on smart and sustainable cities, which has gained global attention as a potential solution to urban sustainability issues. This is especially relevant for cities that are both ecologically and technologically advanced (Bibri and Krogstie, 2017). Previous studies conducted by Vishwanath and Goldhaber (2003) and Schmidhuber et al. (2020) have demonstrated that a user's perception of how easy and straightforward a technology is to use is directly correlated with the success of the product or service. Based on this information, the current study proposes the following hypotheses. By 2050, it is estimated that two-thirds of the world's population will reside in cities, which poses significant challenges to the sustainability of urban systems (UN, 2015; OECD, 2012). These challenges include organizing urban life through infrastructure and built form, ecosystem and human services, and administration. These aspects of urban life are already under immense pressure globally due to the challenge of sustainability and the current wave of urbanization.

Urban sustainability and sustainable urban development have been hot topics in urban planning and design since the early 1990s (Wheeler & Beatley, 2014). Their primary goal is to balance environmental protection and integration, economic development, and regeneration, and social equity and justice within cities to create healthy, livable, and prosperous human environments while minimizing resource demand and reducing environmental impact. By strategically embracing sustainable urban development processes, urban societies can strive towards accomplishing enduring objectives that positively impact both individuals and the environment. Urban innovation is crucial in achieving various objectives within this framework, as highlighted by scholars like (Nam and Pardo, 2011). The advent of smart city technologies has unlocked a plethora of opportunities for urban residents. Smart transportation systems allow seamless connectivity, streamlined traffic management, and expanded mobility choices, reducing traffic congestion and enhancing the overall commuting experience (Nagode et al., 2023). Intelligent energy grids and buildings promote energy efficiency, conservation, and sustainability. By doing so, they reduce carbon footprints and create a more environmentally friendly setting. Smart healthcare solutions facilitate remote patient monitoring, personalized healthcare services, and early disease detection, enhancing healthcare delivery quality (Al-Azzam, 2019). In addition, smart governance initiatives encourage citizen involvement, transparency, and efficient public service delivery, thereby fostering trust and interaction between citizens and government bodies.

Smart city technologies have gained momentum worldwide, with vigor observed in the global North. New York, Chicago, and Barcelona are role models for small and medium-sized cities in implementing smart-city projects. Mainly, New York City has tried to enhance digital accessibility for low-income communities by introducing high-speed internet infrastructure. The installation of Link NYC kiosks, equipped with charging stations and free public Wi-Fi, exemplifies this initiative. Likewise, Barcelona has undergone a significant technological transformation, marked by the widespread implementation of fiber optic networks and the installation of parking sensors. These sensors effectively manage on-demand parking and provide real-time information on availability. Furthermore, the city has established a comprehensive network of sensors to monitor various aspects such as water sprinklers, temperature, sound levels, pollution levels, and foot traffic, underscoring its commitment to smart urban development.

In the global South, the implementation of smart city technology is advancing at a slower and unequal rate. For instance, in Africa, while Cairo is the leader of the world's smartest cities, it occupies the 108th position out of 141. Meanwhile, while Tunisia made its debut in the 2023 annual Smart City Index report, its capital, Tunis, was rated 137th out of 141, with a "D" rating, according to the fourth edition of the report from the International Institute for Management Development (IMD).

The success of smart city programs depends heavily on public support and dedication, regardless of whether they are implemented in the global North or South. Citizens play an essential role in co-creating and co-designing smart city solutions, as their needs, preferences, and behaviors directly impact the efficiency and acceptance of these technologies. Moreover, it is important to consider residents' attitudes when investing in sustainable urban development regarding information and data communication technologies (Wirsinna et al., 2023). Therefore, evaluating the factors influencing citizens' attitudes toward embracing smart city living is crucial. To this debate, our research aims to contribute by answering the question of what factors most significantly influence the behavioral intention of Tunis Metropolitan area citizens to adopt and use smart city services. To do so, it uses the Technology Acceptance Model (TAM) (Davis, 1989) as a base theoretical framework to explore the impact of factors, such as perceived ease of use and usefulness, in explaining citizens' behavioral intention to use smart city technologies. The conceptual model within this paper also explores the role of perceived security and privacy in building trust towards these services, which can ultimately lead to their adoption by citizens.

This paper is structured as follows: Section 1 provides the theoretical foundation of the Technology Acceptance Model (TAM), offering insights into variables that directly predict the behavioral intention of smart city technologies adoption and outlining the hypotheses and the survey design. Section 2 details the results, leading to the discussion (section 3) and the conclusion (section 5).

Background on Smart and Sustainable Cities

II. Material and Methods

1. Conceptual framework and hypothesis

The Technology Acceptance Model (TAM) is a theoretical framework designed to assess and predict the reception of various technologies among their target audiences. Developed by Fred Davis in the late 1980s, TAM offers insight into why individuals use and adopt specific technologies. It gauges an individual's perception of a technology's ease of use, reflecting the perceived effortlessness of its utilization and their perception of its usefulness, indicating the belief that the technology will enhance performance or productivity. TAM posits that these two aspects interact to influence how people utilize and feel about technology. Leveraging a robust psychological and sociological foundation, TAM finds widespread application in diverse scenarios, including smart cities, showcasing its adaptability and utility for examining technology adoption across various contexts (Wirsinna et al., 2023). For example, Habib et al. (2020) study was among the first to use the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003) – which is a more sophisticated and extended version of the TAM framework - to develop a model aiming the understanding of factors that influence residents' intentions to use smart cities services in mid-size U.S cities. The authors offer a valuable framework for analyzing how residents of smart cities respond to and integrate new technologies into their daily lives, particularly in the realm of urban sustainability transition

Following the TAM framework, we postulate that the acceptance of smart city technology and services is predicted by the residents' behavioral intention, which is, in turn, determined by their perception of technology's usefulness in performing the task and perceived ease of its use. Moreover, following Habib et al. (2020), we consider that residents' privacy and security expectations could be sorely challenged as cities become more technologically advanced. Scuotto et al. (2016) even argue that smart city residents will face greater challenges as IoT

sensors and analytics proliferate. As a result, the use of these e-services proves increasingly risk averse. Therefore, we hypothesize that perceived security and privacy influence trust in technology, which, in turn, influences behavioral intention toward adopting smart city technologies. Furthermore, theories on attitudes conceptualize behavioral intention into two main stages, the association of 1. belief attitudes on the one hand and 2. attitude intention on the other (Ajzen & Fishbein, 1980). In the first stage, individuals form their attitudes based on their own beliefs and cognitive processes. In the second stage, these attitudes shape their behavior and determine how they express themselves. Therefore, we hypothesize that the variables Perceived ease of use (PE), Perceived usefulness (PU), and Trust in technology (TT) represent residents' beliefs and affect their attitudes. Attitudes, in turn, will lead to the expression of behavioral intentions.

The following describes the theoretical definitions of the different components of the conceptual model depicted in Figure 1 and tested in this paper.

Perceived security (PS) is the degree to which users consider smart-city services secure platforms for storing and sharing private and personal data and refers to the probability that users believe their sensitive information will not be tampered with or manipulated during transmission or storage by unauthorized persons (Baig et al., 2017).

According to Braun et al. (2018), perceived security is not only determined by technical factors but also includes subjective components related to individuals' perceptions of technology. Chellappa and Pavlou (2002) suggest that robust security technologies such as encryption, protection, verification, and authentication determine people's perception of information security. Goldfinch et al. (2009) also note that environmental factors, such as trust in government electronic services, significantly shape perceived security.

Studies have investigated the challenges in adopting perceived security behavior across various fields, such as cloud computing, e-Gov services, and e-banking (Arpaci, Kilicer, and Bardakci, 2015). When related to smart city services, security can be considered a general component, as it encompasses all the characteristics and aspects of the city (Ristvej et al., 2020).

Schumann and Stock (2014) highlight that users of smart-city services prioritize safety and security, while Chatterjee, Kar, and Gupta (2018) emphasize the importance of quality of information and service quality. Additionally, Edwards (2016) suggests that users prefer increased government regulation. In this research, PS is described as the extent to which users

consider smart-city services secure platforms for storing and sharing their private and personal data. Hence, the following hypothesis was formulated:

H1a. Perceived security (PS) positively affects the Trust in Technology (TT) when it comes to adopting smart city services.

Perceived Privacy (PP): is the degree to which users believe a given technology is safe and will protect their personal information (Arpaci et al. 2015). Privacy is universally regarded as an essential human right. When it comes to information, privacy refers to an individual's fundamental right to manage their private information. This includes deciding how it is collected, shared, and utilized (Grandhi et al., 2021). Privacy concerns hinder the success of e-government initiatives in today's digital environment. This is because citizens are often skeptical and mistrust such services (Gefen et al., 2003). As a result, practitioners and theoreticians have been working to develop better frameworks for measuring information privacy violations, given the continuous rise of AI, IoT, and cloud technologies in recent years.

In the smart city context, PP refers to the individual's perception of control over personal information (Chang et al. 2018). Van Zoonen (2016) suggests that both privacy and security affect factors in smart city models. On the other hand, Yeh (2017) observed that citizens were willing to accept and use smart-city services as long as they were innovative, their privacy assured, and the services themselves high quality.

In this study, we hypothesize that PP plays a significant role in determining trust among the users of smart city services.

H1b. Perceived privacy (PP) positively affects the Trust in Technology (TT) when it comes to adopting smart city services.

Trust in technology (TT): is the expectations of what other people will do in the future based on past experiences (Mittendorf, 2016) and is important factor for establishing relationships, particularly in environments with uncertainty and risk, such as digital transactions. As cities become increasingly connected and dependent on technologies such as IoT and AI, Trust in technology has become a fundamental component in citizens' success and acceptance of these products and services. According to Habib et al. (2020), Trust in technology is correlated with perceived privacy and security, as smart city services typically collect data from different sources such as sensors, cameras, and citizen records. Therefore, citizens need to guarantee that their data is managed securely and safely and that their privacy is protected. On the other hand,

Braun et al. (2018) argue that any concerns related to security and privacy must be addressed before infrastructure changes are inducted if smart-city services are to be successfully adopted. Trust in technology has been shown to influence both residents' attitudes and intentions to adopt smart city services and applications (Flavián and Guinalú 2006), we therefore make the following hypothesis:

H4a: TT mediates the conceptual model's relationship between PS and PP, respectively, on attitudes toward smart-city services.

H4: TT positively affects attitudes toward smart city services.

Perceived Usefulness (PU): refers to residents' perception of the substantial value that smart city services and applications could bring to their lives. As a result, they will be more likely to embrace and engage with these technologies. Indeed, citizens and residents might be willing to use smart city services and applications when they believe that the technology will benefit them over manual or face-to-face procedures for requesting or applying for urban services. According to Chaiyasoonthorn and Chaveesuk (2019), perceived usefulness indicates that individuals assess the expected usefulness of smart city applications and services based on their own requirements, expectations, and past experiences. Overall, residents believe that smart city initiatives and technologies can provide advantages such as convenience, efficiency, improved quality of services, and enhanced sustainability, which will make them more inclined to develop a positive opinion of smart cities and consider adopting them (Baldi and al. 2023, Park and Chen. 2007). We, hence, put forth the following hypotheses.

H2. Perceived usefulness positively affects attitudes toward smart city services.

Perceived Ease of Use (PE) refers to an individual's subjective assessment of the effort required to use smart technology in a smart city effectively. It relates to their perceived ease of understanding and using such technologies (Wirsinna et al., 2023). Urban residents may think smart city technology is complicated to use. This is a significant factor in understanding the acceptance of government e-portals and other smart city services and applications (Schmidhuber et al., 2020). When citizens perceive smart city technologies as user-friendly, intuitive, and easily accessible, their perception of ease of use will improve (Baldi et al., 2023).

Previous studies conducted by Vishwanath and Goldhaber in 2003 and Schmidhuber et al. in 2020 have demonstrated that a technology's perceived simplicity and ease of use significantly impact its success rate. Based on this insight, this study proposes the following hypotheses.

H3. Perceived ease of use positively and significantly affects attitudes toward smart city services.

Attitudes (AT) towards smart city services refer to an individual's positive or negative evaluation of relevant behavior. This evaluation varies from person to person based on their backgrounds and past experiences and is a significant predictor of behavioral intention (Al-Debei et al., 2013; Al-Lozi, 2011). We, therefore, make the following hypotheses:

H5a: Attitudes toward smart city services mediate the relationship between TT, PE, and PU and the intention to adopt smart city services.

H5: Attitudes toward smart cities services positively and significantly affect behavioral Intention to adopt smart cities services.

Behavioral Intention (BI) represents the user’s intention to act on the object of study affected by a set of proposed variables. In this study, this construct was defined as the ‘intention to adopt the smart cities services’ and defined as central in determining an individual’s acceptance of smart city technology.

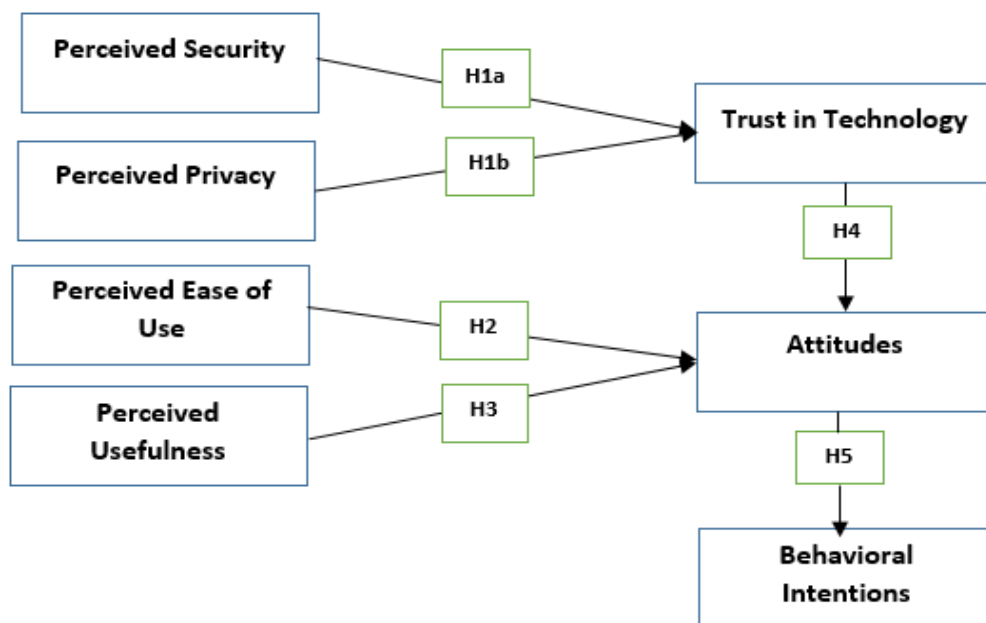


Figure 1 – The tested conceptual model

2. Survey design and measurements

The survey used in this study to collect data was designed with reference to the above-presented conceptual model and was composed of three main sections. After briefly introducing the smart

cities concept and its application in urban areas, the first section included questions to assess respondents' current knowledge and use of smart city services. The second section focused on respondents' beliefs and attitudes and behavioral factors that could influence the adoption of smart city services. Respondents were presented with questions intended to measure the latent variables as presented in the previous paragraph; 26 items were employed to evaluate the variables using a five-point Likert scale ranging from "strongly agree" to "strongly disagree." The components utilized for the Behavioral Intention toward the Smart City services construct definition were derived from previous studies conducted by Venkatesh et al. (2003). The measures employed to evaluate the attitudes toward smart city services, perceived usefulness, and perceived ease of use were derived from the works of Park and Chen (2007). The items used for perceived security and perceived privacy constructs were derived respectively from the works of Bhattacharjee and Park (2014) and Arpaci et al. (2015). Finally, the trust in technology items was derived from Almuraqab's (2017) work.

The third and final section intended to gather data about respondents' socio-demographics, including gender, age, and educational attainment. The survey was shared online and targeted more than 3000 residents of the Grand Tunis Metropolitan area, including four governorates: Tunis, Ben Arous, Ariana, and Mannouba. At the end of the survey campaign from September to December 2023, we obtained 245 completed questionnaires, out of which we only retained 214 that we deemed usable for the following analysis.

Table 1. Measurement items of the survey

Perceived Security (PS)	
PS1	I would feel secure sending my sensitive information via smart city services.
PS2	A smart city website is a safe place to transmit sensitive information.
PS3	I would feel safe storing sensitive information and documents about myself over smart city services.
PS4	I believe that smart city services provide sufficient restrictions for unauthorized access
2. Perceived Privacy (PP)	
PP1	I believe that Smart City services have a strong policy to protect my sensitive information.
PP2	I often look for and read the privacy policies of smart city services
PP3	I am careful not to give service providers more information online than I have to.
PP4	Smart city providers only collect my personal information if necessary.
3. Perceived Usefulness (PU)	
PU1	With the help of smart city services, I could get more done in less time.
PU1	My productivity would increase significantly if I made use of the smart city's offerings.
PU3	The incorporation of smart city services into my daily routine would allow me to do more.
PU4	The smart city services would help me be more productive in my daily life.
PU5	The smart city services will improve my quality of life.
4. Perceived ease of use (PEU)	
PE1	I think I could quickly pick up the skills necessary to use the smart city's amenities.
PE2	I could easily use the smart city services to achieve my goals.
PE3	I could have an easy-to-understand experience with smart city services.
PE4	The smart city services I anticipate using are adaptable and easy to use.
PE5	I could learn to use smart city services in no time.
PE6	The convenience of the smart city services would appeal to me.
5. Trust in Technology (TT)	
TT1	I trust the security of smart city services. The Legal/technical infrastructure of smart city services is sufficient to protect my information.
TT2	I trust the devices that collect and process my data while using smart city services TT3. I can count on smart city services to protect my information.
6. Attitude toward smart cities services (ATT)	
ATT1	Taking advantage of life in a smart city is a promising prospect.
ATT2	It is not fun to use smart city services in daily life.
ATT3	I like (would enjoy) making use of life-enriching smart city services.
7. Behavioral intention (BI)	
BI1	I intend to continue using smart city services in the future.

3. Data analysis and procedure

The data collected from the online survey underwent analysis using STATA software version 16. Most respondents to the survey are female (68%). On average, they are 31 years old and have lived in the Grand Metropolitan area for over 25 years. 42 % of the respondents declare they have earned a master's degree. While 68% have already heard about smart city technologies, only 5% have already used these services, mainly offered by the municipality platform to connect citizens to public services such as obtaining birth certificates electronically. Moreover, although there was an apparent agreement among respondents about the potential of smart city services in reducing cities' ecological footprint and negative impact on the environment (52% totally agree), when asked about the specific functions and role of smart city technologies in meeting sustainability in an urban setting, such as enhancing transportation traffic, reducing air pollution, improving energy efficiency and waste management (Fig 2), most respondent neither agree nor disagree for these questions. These results reveal how complex the concept of smart cities is for the residents of the Tunis Metropolitan area. Although respondents find certain aspects of smart cities appealing and desirable, they may still be uncertain due to a lack of information. The neutral responses from participants indicate the need for more clarification and education on the topic. On the other hand, the neutral responses could suggest that the respondents lack a strong opinion about the different functions of smart city technologies. This could be because these ideas are still new to Tunisian society and public discourse. Therefore, the respondents do not strongly prefer defining them one way or the other. These results highlight the importance of educating the public about smart cities and their various functions.

Moreover, to better understand the relationship between the different components of attitude, we employed the Structural Equation Modeling (SEM) approach, enabling us to accurately measure and describe the complex correlations between various factors (Hair et al., 2012). In this study, we utilized the Maximum Likelihood method of the STATA command language to conduct the SEM. To begin with, the first step involved evaluating and analyzing the measurement model used in this research by using the non-parametric indicator Cronbach's alpha (>0.7), which was analyzed to ensure its suitability for use in the structural model (Bagozzi et al., 1991). Following this, we performed confirmatory factor analysis and examined the results of the structural models. This helped to analyze the internal consistency of the measures and improve the model fit. Additionally, we applied the Satorra-Bentler Estimator to address any potential non-normality of the measures. Lastly, we tested the goodness of fit using

the Root Mean Square Error of Approximation (RMSEA), the Comparative (CFI), the Tucker-Lewis index (TLI), and the Standardized root mean squared residual (SRMR).

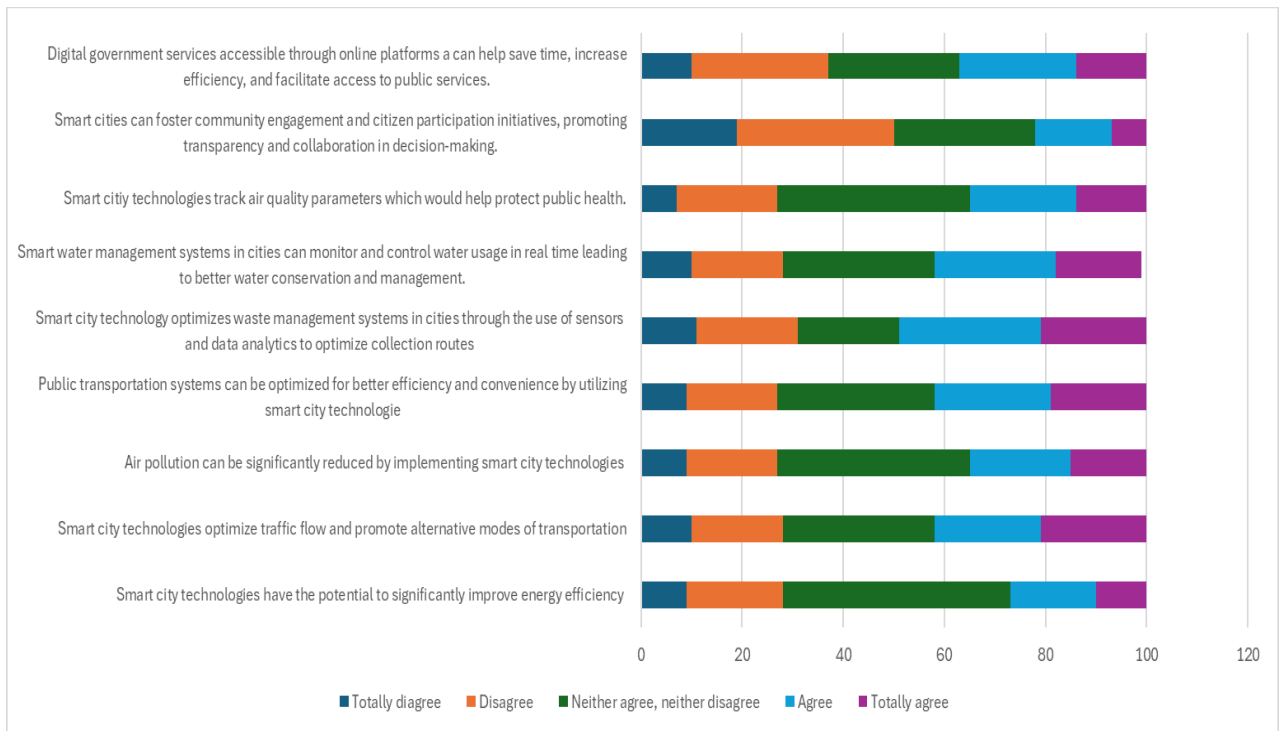


Figure 2. How do Tunis Metropolitan area respondents perceive the influence of smart city technologies on sustainable development?

III. Results

1. Test of the model: the exploratory factor analysis

The exploratory factor analysis examines the assumption that there is a relationship between the items used in the questionnaire to explain residents' behavioral intention to adopt smart city services. The correlation matrix between the measurement items shows that data are not highly correlated¹ (Table 2). Moreover, the Bartlett test was performed. Its significant value ($\chi^2=4067.53$, $p\text{-value} = 0.000$) indicates the availability of sufficient adequate correlations. The value of the Kaiser Meyer Auckland measure of sampling adequacy ($KMO = 0.915 > 0.50$) is also significant, confirming that there are significant intercorrelations between data and, therefore, the relevance of running the factor analysis.

Table 3 presents the results of the explanatory factor analysis for the measurements scale. Hair et al. (2020) method for items' reliability and validity was verified through Cronbach's alpha

¹ Data are not being highly correlated is a positive sign, because if they were too highly correlated, they are not uniquely explaining the matrix.

and Dillon-Goldstein's rho, which were, in our case, higher than 0.7 and 0.8, respectively. Therefore, items with a factor loading below 0.7 were deleted, which was the case for [PE6], [PS3], [PP5], [PU4] and [PE1] items.

Table 2. Correlation matrix of the measures

	Perceived Security	Perceived Privacy	Perceived Usefulness	Perceived Ease of Use	Trust in Technology	Attitude	Behavioral Intention
PS1	0.903	0.568	-0.015	0.503	0.536	0.523	0.654
PS2	0.901	0.492	0.017	0.479	0.455	0.397	0.586
PS4	0.901	0.597	-0.072	0.382	0.017	0.151	0.523
PP1	0.505	0.862	-0.102	0.467	0.016	0.597	0.597
PP2	0.490	0.909	-0.039	0.164	0.332	0.338	0.572
PP3	0.493	0.888	0.060	-0.137	0.115	0.596	0.511
PP4	0.500	0.872	0.024	0.491	0.127	0.047	0.493
PU1	0.297	-0.075	0.896	0.471	0.068	0.596	0.490
PU3	0.562	0.035	0.892	-0.026	-0.104	0.507	0.493
PU5	0.233	0.156	0.888	-0.276	0.515	0.387	0.596
PE2	0.387	0.410	-0.034	0.896	0.459	0.544	0.343
PE3	-0.056	-0.101	0.544	0.892	-0.075	0.387	-0.177
PE4	0.164	0.068	0.387	0.909	0.035	0.471	0.085
PE5	-0.137	-0.104	0.471	0.888	-0.103	-0.026	-0.276
TT1	0.472	0.470	-0.024	0.443	0.831	-0.077	0.518
TT2	0.627	0.459	-0.077	0.469	0.865	0.544	0.655
ATT1	0.520	0.650	0.025	0.468	0.732	0.887	0.632
ATT2	0.490	0.596	0.515	-0.072	0.586	0.911	0.518
ATT3	0.493	0.507	0.484	-0.102	0.518	0.896	0.443
BI	0.632	-0.130	0.521	0.668	0.677	0.717	1.000

Table 3. Psychometric properties of measurement scales

Latent variable	Dimensions	Factor loading	Cronbach's alpha	AVE
Perceived Security	PS1	0.903	0,896	0,786
	PS2	0.901		0,82
	PS4	0.901		0,773
Perceived Privacy	PP1	0.862	0,862	0,813
	PP2	0.909		0,786
	PP3	0.888		0,876
	PP4	0.872		0,841
Perceived Usefulness	PU1	0.896	0,923	0,864
	PU1	0.892		0,813
	PU5	0.888		0,788
Perceived Ease of Use	PE2	0.896	0,862	0,745
	PE3	0.892		0,727
	PE5	0.909		0,79
Trust in Technology	TT1	0.831	0,912	0,798
	TT2	0.865		0,742
Attitudes	ATT1	0.887	0,912	0,867
	ATT2	0.911		0,813
	ATT3	0.896		0,802

2. Confirmatory Factor Analysis

A Confirmatory Factor Analysis (CFA) was carried out to validate the reliability of the chosen measures for the structural model. This was done in addition to the previously conducted Exploratory Factor Analysis (EFA). Although the factorial structure of the constructs: PS, PP, PE, PU, and TT, can be considered established due to the extensive literature dealing with different contexts of technology use, the exploratory factor analysis was conducted to refine and tailor the measurement items according to the specific context of the nascent movement of smart cities in the Grand Tunis Metropolitan area.

Our findings indicate that our model fits well with the data. The RMSA values are below 0.05, which is considered a good fit according to Pituch and Stevens (2016). The CFI and TLI are incremental fit indices, and values above 0.95 suggest an excellent fit. Additionally, the SRMR values above 0.10 are considered a good fit and are satisfactory for all variables. As a result, they were included in the baseline structural equation model (SEM).

3. The Structural Equation Model

The purpose of the study was to investigate the relationship between several factors, including perceived usefulness, perceived ease of use, trust in technology, attitudes, and behavioral intentions of Grand Tunis Metropolitan area residents towards using smart city technologies. We used a Structural Equation Model to analyze this relationship. However, the initial baseline model fit was not satisfactory, indicating the possibility of a specification error. To improve the model specification, we followed MacCallum's (1986) suggestion to allow covariance between the latent variables. The modification indices for path coefficients and covariances indicated that adding a covariance between perceived usefulness and perceived ease of use improves the model's fit. After the modification, the new model fit was satisfactory, with a lower RMSEA_SB value (0.084), higher CFI_SB (0.927) and TLI_SB (0.906) values, lower SRMR (0.081), and CD (0.999).

Table 4 presents the final test of the independent variables' contribution to residents' attitudes toward smart city technologies. The three variables PU, PE, and TT influence attitudes toward smart city technologies, with PE ($B = 0.395$; $t = 6.323$) and TT ($B = 0.319$; $t = 5.124$) making an essential contribution to attitudes. These results support H2 and H4, respectively. However, contrary to the research model, PU did not significantly contribute to attitudes toward smart city technologies ($B = 0.076$; $t = 1.321$); thus, H3 was rejected. There is also a positive and significant relationship between perceived security and trust in technology on the one hand and between perceived privacy and trust in technology on the other. These results confirm H1a and H1b, respectively. The validated model of the determinants of BI to use smart city technology is presented in Figure 2.

Table 4– Contribution of the independent variables to the behavioral intention to use smart city technologies.

Model Adjustment	Dependent variables	Independent variables	Standardized Path	Standard Error	Critical ratio (CR)	Pr > t (5% risk of error)	Hypothesis	Results
R ² =0.447 F =59,93	Perceived trust	Perceived security	0.412	0.043	9913	0.000	H1a	Validated
		Perceived privacy	0.311	0.050	7912	0.000	H1b	Validated
R ² =0.116 F = 34,874	Attitudes	Perceived trust	0.319	0.070	5124	0.000	H4	Validated
		Perceived usefulness	0.076	0,058	1321	0.189	H2	Rejected
		Perceived ease of use	0.395	0.053	6323	0.000	H3	Validated
R ² =0.557 F =53,96	Behavioral intention	Attitudes	0.410	0.011	7120	0.000	H5	Validated

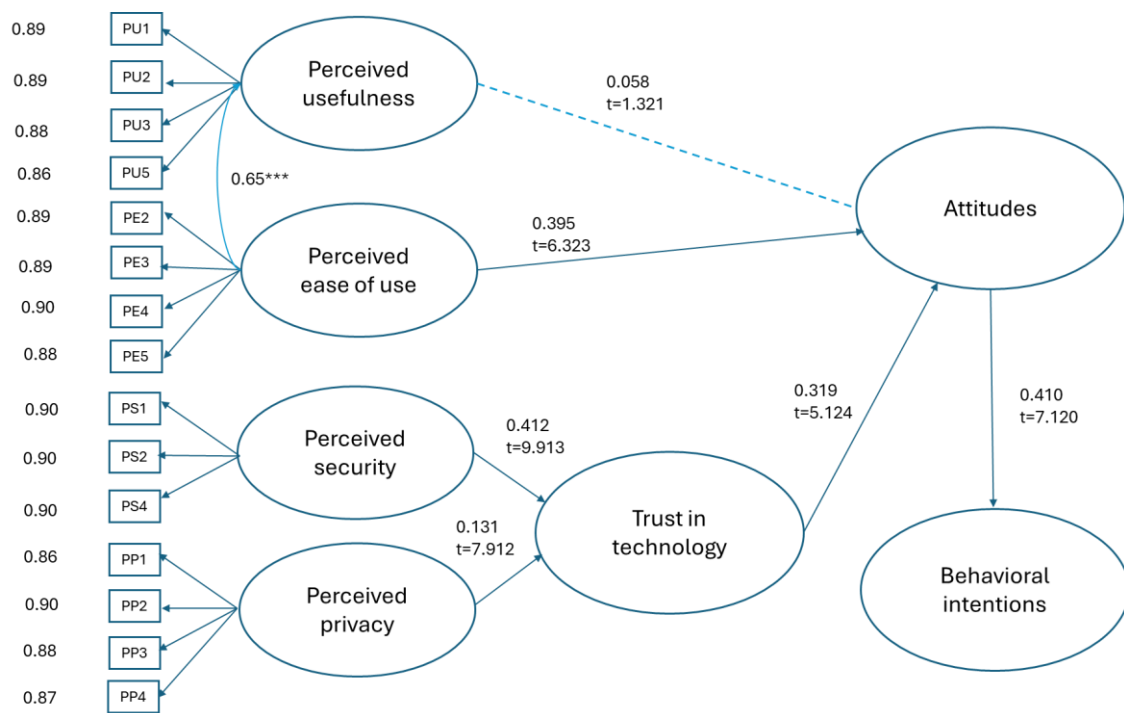


Figure 2. Path diagram for the tested structural model

Discussion and conclusion

This paper was the first investigation in the literature into the factors influencing citizen adoption of smart city technologies in the Grand Tunis Metropolitan area. It explored how factors such as trust in technology, perceived ease of use, usefulness, security, and privacy could affect citizens' behavioral intention toward smart city technologies. Smart city technologies in Tunisia are still at a nascent stage, making it crucial to understand the factors necessary for their practical and sustainable implementation.

Our findings suggest that respondents' attitudes towards adopting smart city services are significantly influenced by their perceived ease of use, followed by trust in technology. However, in contrast to most contexts of application of the technology adoption model, usefulness has not significantly contributed to the final tested model that still highlights a significant correlation between perceived ease of use and perceived usefulness. These results align with early e-government studies by Alawadhi and Morris (2008). Perceived ease of use was found to be understood as convenience. It was a leading factor in adopting cloud technologies in a study by Arpaci (2016) as well as Gupta et al. (2013), stating that respondents believe smart city technologies and services will be easy to grasp and use, and they are mainly interested in convenience. Moreover, the importance of designing new services that are intuitive and easy to use while also providing convenience is highlighted by the statistical significance of ease of use over perceived usefulness.

Our research shows that people's trust in technology plays a significant role in their perception of smart city technologies and services. It is more likely for people to use various technologies and services when they feel that their personal information is safe and their privacy rights are being respected. Studies on e-government, e-banking services, mobile applications, and big data analytics all support this finding. While most of these studies have been conducted in North America and Europe, a research conducted by Saif Almuraqab et al. (2017) revealed that security challenges were the primary factor in the adoption of IoT technology in the United Arab Emirates, which corroborates our findings. Conversely, Ratten (2014) argued that trust, performance, and innovation significantly influence users' behavioral intention to adopt technological innovations. Alhogail (2018) also suggested that security-related factors determine trust towards IoT adoption and improve the overall technology adoption rate. Therefore, trust in technology is a crucial factor in adopting smart city technologies and, in our

model, even outperforms perceived usefulness on its influence on attitudes toward smart city technologies and services.

Tunisia's first attempt to implement smart city services has been through e-government services. These aim to simplify the process of dealing with governmental and large bureaucratic institutions and receiving services face-to-face, which can be complex, time-consuming, and inefficient. However, according to our questionnaire, a major part of the respondents are still unclear about how smart city technologies can lead to efficiency and overall sustainability in the urban environment. It appears that the majority of respondents don't have a definitive viewpoint on the various functions of smart city technologies. This could be due to the fact that these concepts are still relatively new to Tunisian society and have yet to be fully discussed in the public domain. Consequently, it seems that the respondents don't strongly lean towards defining these functions one way or the other which could also explain why performance expectancy is not significant in our final model. These findings underscore the need for greater education and awareness among the public regarding smart cities and their diverse range of functions. According to the 2023 Smart City Index report, it is crucial to adopt an educational and empowering approach that supports the human capital of smart cities. This means that cities should focus less on technology and more on people to be considered truly smart. It's essential to raise awareness and provide education to reinforce how residents perceive the structures, technologies, and applications available to them in their city.

Finally, our study's findings provide valuable insights for policymakers and urban planners seeking to develop and implement smart city technologies in the Tunis metropolitan area. Adopting smart city technologies is crucial in achieving sustainable urban development, and it is essential to ensure that citizens' needs and concerns are addressed to enhance their acceptance and use of these technologies. Further research is needed to explore other factors influencing citizens' adoption of smart city technologies and how these factors may vary across different regions and contexts in the MENA and African regions.

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