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The relationship between citizen readiness and the intention to continuously use smart city services: Mediating effects of satisfaction and discomfort

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ABSTRACT

The principal goals of smart cities are to improve citizens' quality of life and foster economic growth while ensuring efficient service delivery and sustainable development. Accordingly, understanding and adequately meeting citizens' needs and desires is a fundamental step toward improving citizens' happiness. While prior studies have investigated the direct relationship between technology readiness and continuous intention to use the services, extant results are still fragmented. Hence, this study examines the relationship between citizens' readiness and intention to continue usage by introducing satisfaction and discomfort as mediators in a smart city services (SCS) context. We rely on a mixed-method approach to propose and validate a new readiness model for assessing smart city citizens' readiness for continuous usage and long-term adoption of SCS. In the first phase, qualitative research was used by conducting in-depth interviews with SCS experts to investigate and theorize the main factors perceived as enablers and inhibitors to the continuous usage of SCS. While in the second quantitative phase, data were collected from 350 citizens and structural equation modeling was employed to test the proposed hypotheses. The findings suggest three main enablers (empowerment, optimism, and innovativeness) and three main inhibitors (insecurity, mistrust, and legal considerations) that affect the intention to continuously use SCS. In the quantitative phase, satisfaction and discomfort emerged as mediators to intention of continuous usage. Moreover, we found that empowerment, innovativeness, and optimism enhance the continuous usage of SCS when mediated by satisfaction but have no significant effect when mediated by discomfort. Discomfort was found to be an effective mediator between inhibitors and continued usage intention. Our study highlights the role of technology readiness as a personality trait in shaping user satisfaction, discomfort, and intention to continue using SCS. Furthermore, it proposes a new scale and model for measuring users' readiness to adopt and continuously use SCS. The proposed model has practical implications for SCS providers, and can inform the design of future SCS and ensure their sustainable and successful adoption by citizens, not only initially, but also in the long-term.

1. Introduction

Anchored in the 2030 Agenda for Sustainable Development is the ushering in of smart and sustainable cities [1]. With the rapid industrialization in developing economies, population growth, and rural-urban migration in most nations around the world, the need to create smart and sustainable cities has become a strategic imperative for countries [1,2]. Indeed, the growth of the urban population could lead to

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over 300% rise in both energy and material use [3]. By 2050, around 66% of the global population will be situated in urban areas, further exacerbating the trend and need to develop sustainable cities [4]. With the world population expected to reach 10 billion by the year 2057 from around 7 billion in 2020 [5], smart cities are a growing trend in how we envision technology to help address urban challenges and problems [2]. Smart cities are expected to enable nations to meet the UN Sustainable Development Goals and achieve environmental sustainability. Although the use of ICT to enable better and more customized services and deliver improved public policy decisions are a common theme in smart city (SC) literature [4,6], the means and paths to becoming 'smart' are far from clear. The lack of a unified definition is evident in the generic characteristics that the label proposes [7].

To understand the meaning of a smart city, one must first consider the changing nature of its discourse over the past twenty years. A key point in the smart city discourse is the emphasis on ICT deployment and the digitalization of city services. In this sense [8], defines a smart city as "*a city that monitors and integrates conditions of all of its critical infrastructures, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens*." Reference [9] proposes a similar concept, in which smart cities make use of smart computing technologies to render the critical infrastructure components and services of a city more intelligent, interconnected, and efficient. While proposing an approach that considers the spatial dimension of smart cities [10], defines those cities as "*all urban settlements that make a conscious effort to capitalize on the new ICT landscape strategically, seeking to achieve prosperity, effectiveness, and competitiveness on multiple socio-economic levels.*" In Ref. [11], Holland regards the smart city as an urban label phenomenon and unravels its discourse to understand its key elements. According to Holland, the main aspects of a smart city include the use of ICT to connect infrastructure systems and further their potential, a general belief in entrepreneurial urban development, and, in some cases, a tendency to address social or environmental aspects of urban development. However, Holland raises the concern that the creative/human/eco-city discourse might be a façade for a blander hi-tech urban development agenda and further argues that social and territorial aspects are critical to developing a more 'progressive' smart city.

This perspective is reflected in later definitions, which recognize a general insufficiency of ICT-focused definitions and consider the smartness of citizens and society as a whole. Some contend that smartness arises when a combination of human and social capital is employed along with infrastructure (both traditional and modern) to promote the quality of life and sustainable development [12]. The importance of citizens' participation aimed at better managing resources is also stressed as a key aspect of a smart city. Nam and Pardo [10] define smart cities as the use of ICT to deliver better services and quality of life to the population. They argue, however, that a city should be understood as a complex 'system of systems' and that the social, as well as technological aspects, must be considered. To achieve this objective, they propose an approach that considers technological, institutional, and human factors. This approach is further developed into a framework with four major dimensions: technology, organization, policy, and context [10].

Neirotti et al. [7] have empirically shown that smart city literature can be classified based on its emphasis on either the 'hard' or the 'soft' domains. This indicates not only the strong dependency of definitions and tendencies on local context variables but also the lack of a 'unique, global definition' of a smart city. Albino et al. [2] also recognize the plurality of definitions arguing that cities must employ tailor-made frameworks that consider their specific challenges and priorities to promote integrated development of different aspects, both hard and soft [2]. Moreover, Yigitcanlar et al. ([13], p. 157) argued that "despite [the] high-level popularity of [the] smart cities concept and practice, there is no consensus on what a smart city is, what [...] the key smart city drivers and desired outcomes are, and how the smart city paradigm can be conceptualized ...".

Overall, the concept of a smart city has undergone a series of changes over the past two decades. Initially focused almost exclusively on the deployment of ICT and infrastructure, the discourse gradually began to include initiatives to enable social and human capital and, eventually, revolve around the improvement of citizens' quality of life [14]. In this work, we propose a definition of smart cities that is in line with this evolution, namely: *a smart city employs technology, in both the hard and the soft domains, to improve the happiness and quality of life among its citizens and inhabitants.*

While the technological and infrastructural dimensions of smart cities have been discussed widely in previous studies, there is still a need to further and more deeply understand the social, cultural, and territorial dimensions of smart technology applications [10,15,16]. When using technology to enable smart city services (SCS), it is crucial to consider the social aspects that permeate the urban phenomena to address the development of a more progressive smart city [11]. Social, regional, and demographic dimensions are essential in contextualizing technology, and they provide an adequate background for understanding how citizens interact (or not) with SCS [16,17]. Accordingly, understanding and adequately meeting citizens' needs and desires is a fundamental step towards delivering better services and, eventually, improving happiness and citizens' quality of life [14]. Of particular relevance to this goal is the assessment of citizens' technology readiness (TR) to use SCS, and which readiness factors will impact their intention to continuously use those services [18,19]. While an enhanced understanding of technology readiness aspects is critical, limited studies have addressed this topic [20].

According to Parasuraman [21], TR is defined as "people's propensity to embrace and use new technologies for accomplishing goals in home life and at work." Extant literature in the technology readiness area suggests that users' personalities should be considered to predict their perceptions and behaviors [21]. Zeithaml et al. [22] proposed the "Pyramid model" as an extension of the "Triangle model" proposed by Ref. [23] that didn't explicitly consider the impact of technology on the provided service. To address this issue, the pyramid model incorporates technology as a new dimension and creates three new concepts to enhance service marketing effectiveness: 1) company technology, 2) technology's employees, and 3) technology's customer. These concepts were used to develop the technology readiness index 1.0 (TRI 1.0) [21] and the technology readiness index 2.0 (TRI 2.0) [24] as multi-item scales to assess people's technology readiness. The concept of TR is multi-faceted, including four main dimensions: optimism, innovativeness, discomfort, and insecurity. Optimism pertains to a positive view about technology that is seen as an enabler to a more efficient and flexible lifestyle. Innovativeness is related to the tendency to embrace change and being a thought leader and pioneer when it comes to innovations. Discomfort reflects a feeling of being overwhelmed by technology and not having control over it, while insecurity is related to skepticism and lack of trust in technology. The TRI (Technology Readiness Index) is considered as a seminal scale in service research and was adopted by hundreds of studies in many countries worldwide, such as [25–28]. Likewise, research emphasized customer characteristics and traits as a primary factor affecting the perception and adoption of smart services [29].

Meanwhile, a meta-analysis conducted by Ref. [30], assessed the conceptualizations of TR and its impact on technology usage. Their results established stronger relationships for enablers than inhibitors thereby suggesting further research to examine TR's dimensions through different mediators. In particular, prior research evidence suggests that user satisfaction is one of the critical factors of new services' success [31–34] and as a result, many scholars have focused on understanding the impact of customer satisfaction on the intention of continuous usage [35]. According to the theories presented in Refs. [36,37], human behavior is guided by behavioral intentions and influenced by satisfaction. Thus, it is apparent that the relationship between TR as a personality trait, and users' satisfaction and continued service usage as post-adoption behavior requires further investigation [38]. The extant literature also calls for further empirical studies to investigate the relationships between TR and customer satisfaction and intention to use in a variety of industries [39], yet, a few of such studies exist in the technology domain, especially, in SCSs.

On the other hand, existing models such as TPB explicitly includes perceived behavioral control as a determinant of behavioral intention [40]. In the SCS context, discomfort is related to users' fear towards their intended use of SCS such that people with a high level of discomfort find using technology unpleasant and overwhelming and try to avoid it [30]. Several prior studies that have included discomfort as independent dimension in their data failed to establish discomfort as an inhibitor of TR in the technology sector [e.g. 41; 42; 39]. Others [43,44] have tried to test the moderating effect of discomfort on the intention to use digital services but the findings were not significant. Therefore, to help circumvent these contradictory and fragmented results, the current study will test discomfort as a mediator using TRI.02.

Aiming at addressing this issue, the main purpose of this research is to develop a framework to empirically investigate and answer the following research questions "*Which technology readiness factors influence citizens' satisfaction and their intention to continuously use SCS?*" and *"Do satisfaction and discomfort have mediating effects on the relationship between technology readiness and intention to use SCS?"*. We argue that designing future SCS that are aligned with users' expectations and personality traits is critical for deriving users' engagement and satisfaction, and reducing their discomfort, and is of paramount importance for ensuring the continuity of usage and sustainability of these services.

To develop our framework, we propose an extended TRI scale that addresses the specific characteristics of smart services. Furthermore, we investigate the issues related to citizens' intention to continuously use SCSs to gain a better understanding of how to enable the successful adoption of SCS. Hence, this paper contributes to the literature on smart cities in several ways:

- First, it contributes to smart cities' research [2,4,45] by deepening our understanding of citizens' readiness to adopt and continuously use future SCS. Also, it addresses the modeling of citizens' TR in the context of smart cities as a means to determine which factors can influence user retention and post-adoption behavior.
- Second, drawing from the current literature on SCSs in general and the data on SCSs in the United Arab Emirates (UAE) in particular, this study proposes and validates a model for the development of future SCSs that is more in tune with citizens' expectations and personality traits. Practically, this model can help smart city solution providers to better align their services towards the improvement of citizens' quality of life and happiness – happiness being a key objective in smart city initiatives in the UAE [46]. The findings from this work can inform the design of future SCS and ensure their sustainable and successful adoption by citizens, not only initially, but also in the long-term.
- Third, according to our knowledge, this is the first study to empirically examine the mediating effects of both satisfaction and discomfort on the relationships between TR and intention to use SCSs. It is imperative that smart city providers should monitor citizen's readiness in terms of managing discomfort as well as satisfaction levels as these influence users' behavioral intention to adopt SCSs.
- Further, this study contributes to the research work on citizens' readiness for, and acceptance of, future SCSs, by proposing an enhancement of the TRI 2.0 scale [24]. TRI is a seminal scale for assessing people's readiness for embracing and using new technologies. This scale has been used in more than 30 countries for assessing technology-based service delivery models. Given that smart services are the envisioned services in future smart cities, and our goal is to investigate the role of TR in shaping user satisfaction and intention of continued usage of SCS, we believe that TRI is the ideal model to build upon. By leveraging the key constructs of TR, and adapting them to the unique characteristics of SCS, we aim to build a customized readiness scale for those services, in the context of smart cities. This is because readiness and acceptance are critical for the success and sustainability of those services.

The remainder of the paper is organized as follows: Section 2 reviews the relevant related work. Section 3 presents the used research methodology. The results and the proposed model are presented in section 4, followed by a discussion of the findings and their implications in section 5.

2. Literature review

In this section, we begin by discussing our theory and then we discuss the relevant prior literature related to the two mediating variables used in this study (i.e. satisfaction and discomfort). More specifically, we discuss works addressing citizens' satisfaction with technology as well as works addressing citizens' discomfort with technology.

2.1. Theoretical background

Until now, most of the theories proposed to model individuals' behavior theories toward new technology (e.g., technology acceptance model–TAM [47]; theory of planned behavior TPB [48]; and theory of reasoned action (TRA) [37,40]), view the intention of continuous usage as an extension of acceptance behavior. Such theories employ the same constructs to measure both the initial acceptance of the technology and the intention to use it in the future continuously. Therefore, such theories are unable to explain the cases of discontinued use of new services, despite an initially high acceptance rate [49]. However, when investigating technology adoption by the elderly, the authors in Ref. [50] proposed a variation of TAM - The Senior Technology Acceptance Model (STAM). Hybrid models have also been proposed for other contexts. For example, the authors in Ref. [51] merged the TAM with the Theory of Planned Behavior (TPB) and Information System Success (ISS) models to explore the performance of e-government services. In addition, the authors in Ref. [52] propose the Unified Theory of Acceptance and Use of Technology (UTAUT) in an attempt to build a definitive model. Also, related research [53], have explored the user acceptance of business intelligence systems in Taiwan's by applying the UTAUT model. As a result, building on these existing approaches, we use UTAUT to develop and test a model that focus on modeling citizens' technology readiness in the context of smart city services to determine which readiness factors can influence post-adoption behavior and continuous usage. The proposed model can inform the design of future SCS and ensure their sustainable and successful adoption by citizens, not only initially but also in the long-term.

2.2. Citizens' satisfaction with technology

Despite the extant divergent views towards defining the concept of customer satisfaction in smart services, clearly, the evaluative process-oriented approach has been regarded as the most effective way to measure the level of customer satisfaction [54]. Based on this definition, some scholars have operationalized satisfaction as a mediator to determine the drivers of intention to use these services (e.g. 55; 56; 57]. In Ref. [55], the authors investigate the service quality perception of Pakistan International Airline passengers, using SERVQUAL, as data collection tool. The results show that passengers' satisfaction acts as mediator for the relationship between service quality and behavioral intention. The researchers in Ref. [56] analyzed the mediating effects of customer satisfaction on repurchasing intention in an online shopping context. The online website quality encompassed many aspects such as ease of understanding, information usefulness, website design, ease of use, customization and others. The quality was found to positively impact customer satisfaction and repurchase intention. Customer satisfaction we found to have a full mediating effect on repurchase intention. Focusing on the hospitality sector, the authors in Ref. [57] investigated the impact of service quality and service value on customers' behavioral intention, using satisfaction as a mediator. While service quality and service value were not found to have a direct impact on behavioral intention, customers' satisfaction was shown to have a partial mediating effect.

Focusing on the smart cities' context, one should consider that, while the range of possible data collection channels in SCS allows for more service customization and sophisticated features than in traditional e-services, this same characteristic also accentuates issues about trust and accessibility, even among those with technology skills [45]. A citizen-centric approach to SCS design should consider these challenges to understand how the proposed services will affect the lives of citizens, while also paying close attention to people's expectations in adopting new services. Failure to do so might result in citizens with unmet expectations, low service adoption rates, and high levels of dissatisfaction towards city administration [14]. As demonstrated in Ref. [58], it is possible to assess the degree to which citizens' needs are addressed by measuring citizens' satisfaction with services. This corroborates with the findings of Alawneh et al. [59] in their investigation of the main drivers of citizen satisfaction in Jordan's e-service portal. In that study, the authors concluded that to understand citizens' satisfaction with e-services, one must first understand citizens' needs and expectations.

While satisfaction has previously been linked to the successful adoption of smart and e-government services [59–61], it is in post-adoption behavior that the users' intention of continued use of services can be better assessed. In this sense, prior research shows that satisfaction with service usage is strongly correlated with positive post-adoption behavior such as the intention of continuous usage or user retention [18,62]. Lin and Hsieh [63] highlight the positive relationship between high technology readiness and high satisfaction towards services, which in turn is related to the probability of behavioral intention towards usage. In addition [62], argue that it is of vital importance to directly address users' technology readiness both by reinforcing motivators and by reducing inhibitors to readiness. Appropriately representing and modeling technology readiness in the context of SCS is, therefore, of paramount importance for a successful smart city and service design. In that regard, some scholars have successfully modeled the factors that determine the success of applying the smart city concept from the community but not individual perspectives by using the TRI model, TAM, and the Delone McLean Model [64]. Another study by Ref. [65] evaluated the smart city readiness model design based on the technology-organization-environment (TOE) framework and the results revealed a significant relationship between those three readiness elements and smart city adoption decisions. In addition [66], examined the citizens' readiness to implement crowdsourcing services of a smart city based on an analysis of crowdsourcing models and their application in various fields, such as traffic, environmental conservation, utility services, and health. Their results showed that citizens are ready to accept crowdsourcing services related to environmental conservation and public transportation. Meanwhile, an empirical analysis of measuring and assessing smart city readiness in Iran addressed the importance of cities' technological, socio-economic, and political readiness vis-à-vis the desired transition [67]. Moreover [68], investigated the citizens' preferences and perceptions about SCSs in Taiwan and found that perceived smart services is important and useful and the citizens expressed relatively higher preferences towards the "hard" attributes than the "soft" ones.

On the other hand, several studies have highlighted the need for new models to represent and measure the intent of continuous usage, considering citizen satisfaction on multiple dimensions [35]. For instance, in the context of smart cities [14], assessed the perception of quality of life in a smart city in Brazil and analyzed the main elements of citizens' satisfaction with their home city. However, Macke et al.'s study called for a better understanding of the planning and management of smart cities and their effects on citizens. Furthermore [38], evaluated the impact of citizen participation on satisfaction in a smart city and the results confirmed that citizen participation produces a direct and significant positive impact on satisfaction. Also [69],'s study sought to examine the critical drivers of empowerment and subsequent satisfaction of the features or characteristics of the SCS App in Jakarta (Indonesia). The results showed that SCS gives citizens more feelings of control that, in turn, increases satisfaction with both the App and the government. Weerakkody et al. [70] investigated the impact of satisfaction on e-government services adoption in the UK. The results showed that information quality, system quality, trust, and cost have a significant impact on user satisfaction of e-government services. Focusing on citizens' engagement and participation in smart cities, Lebrument et al. [71] identified three key antecedents to citizens intention to participate in smart city projects, namely: political efficacy, the sense of belonging, and public administration satisfaction. Due to the emerging and evolving nature of smart cities, few studies investigate the relationship between TR, citizens' satisfaction, and their intention to use SCS. This study addresses this gap and builds on findings from the literature, by considering the impact of two mediators on the relationship between technology readiness and the intention to use SCS, namely: Satisfaction (representing positive emotions and perceptions) and discomfort (representing fear and negative emotions and perceptions).

2.3. Citizens' discomfort with technology

User discomfort is defined as the lack of control over technology and a feeling of being overwhelmed by it [24]. In the smart city context, discomfort is therefore related to users' fear towards intention to use SCS. The poor design of the SCSs can derail users towards its adoption [72]. Hence, fear and anxiety should also be considered during SCS design and implementation processes, otherwise, it will reduce citizens' intention to use SCSs. For example, research shows that the operator's access to private data increase citizens' discomfort and reduces their adoption of the new services [73]. Also [74], explored the user acceptance of business intelligence systems in Taiwan's by applying the UTAUT model and found that discomfort is a significant determinant of users' behavioral intention to use technologies.

Discomfort and insecurity have been operationalized as *inhibitors*–the negative dimensions of TR. However, in this study, we treat one of these two traits (discomfort), as a mediator, a proposition that is firmly grounded on both prior research and anecdotal evidence. For example, TPB explicitly includes perceived behavioral control as a determinant of behavioral intention [40]. This suggests that discomfort, as an individual's trait, has a potential negative effect on adoption intentions, such that, people with a high level of discomfort find using a technology unpleasant and overwhelming and thereby try to avoid it [30]. Next, when [75] tested discomfort to evaluate TR in self-service technologies, their result could not confirm discomfort as an antecedent. Also [42], have reported similar problems and as a result, the authors dropped the discomfort construct from further analysis despite being included in the overall formative TR index. A recent study by Ref. [39] investigated the effect of airport self-service characteristics on passengers' technology acceptance and behavioral intention and found that discomfort had no significant effect on behavioral intention. This is also consistent with the results of [76] that revealed discomfort an inhibitory variable of TR to have no significant effect on behavioral intention.

Other scholars have operationalized discomfort differently. For example [43], tested the mediating effect of service satisfaction and the moderating effect of discomfort on intention to use digital ticketing in sports market. Their results strangely found that satisfaction and continued intention were stronger for consumers with high psychological discomfort. In addition, a recent study by Ref. [44] examined the moderating role of technology discomfort on the factors affecting behavioral intention to use e-Pharmacy services using the UTAUT-2 model. The results found that technology discomfort has no moderating effect on the relationship between behavioral intention and actual usage behavior. Based on this evidence showing the lack of converging results regarding the operationalization of discomfort, in this current study, we propose and test discomfort as a mediator using TRI 2.0. The following sections discuss our research methodology and data collection approach, then present the results' analysis.

3. Research methodology & data collection approach

Given the exploratory nature of this research that aims to provide context-specific findings, we relied on a mixed method research approach that is depicted in Fig. 1. The approach adopted combines qualitative analysis with extensive quantitative research to collect the needed data to test and develop our model. The study starts by identifying key aspects and characteristics pertaining to smart city services from the literature (i.e. aspects analysis), and a qualitative research phase, aiming at identifying the key constructs/themes and defining the hypothesis for our study. This was followed by a mapping of the identified themes to the TRI 2.0 related dimensions, to operationalize the themes obtained and define the items of our survey tool. This survey is used as part of our quantitative research phase aiming at testing our hypotheses and generalizing the findings in the form of a readiness model for smart city services.

In the qualitative research phase, we conducted a series of semi-structured interviews with smart city experts to gain deep and rich insights about SCS. Such insights were leveraged for the development of our theoretical research framework and our hypotheses, which were inspired by TRI 2.0 - building on its concepts to address the unique characteristics of smart services. The quantitative research phase consisted of survey data collected from 350 citizens, as means to test our hypotheses and validate our structural model. This combination of two research approaches [77,78] is known to enhance data reliability, produce better constructs and prepositions [79–81] and enhance the validity of research measurements [82].

The qualitative and quantitative research phases were both conducted in the UAE, where the urban population is expected to reach 8.6 million by 2025–which will account for 87.6% of the country's population [83]. Such rapid population growth puts significant strain on the city's resources and operations. The UAE is expected to welcome 45 million people by 2025, including 31 million international tourists. Moreover, the UAE has been consistently ranked as having one of the highest annual carbon footprints per capita. To address those challenges, the concept of smart cities is being contemplated in the UAE and is attracting significant attention from UAE government officials and strategists. Considering the UAE's cities as emerging smart cities with unique and diverse demographic characteristics motivated its choice as a research setting for our study. In the next sections, we present the qualitative and quantitative phases of the study.

3.1. Study 1: qualitative research phase

In the qualitative research phase, we conducted a series of semi-structured interviews with smart city experts to gain insights about the unique characteristics that differentiate SCS from the traditional services, as well as the enablers and inhibitors that would impact their adoption. The interviewees included academic and industry consultants – this balanced composition helped ensure that the whole industry is represented, thus reducing social bias [84–86].

A total of eight smart city experts who resided in the UAE participated in the qualitative research phase. Four of the participants are academics who specialize and conduct research in the area of smart cities, while the other four participants are industry experts with practical experience with new and innovative smart city services being developed and introduced. As our goal of this qualitative phase was to gain initial insights, data collection was completed after reaching theoretical saturation, that is, when the we could no longer identify a new category or theme from the interviews. This sample size is comparable to related research that utilized qualitative interviews [e.g., 85, 86]. Snowball and referrals were used as sampling technique to identify those experts. That is, the researchers began by identifying a few smart city experts within their social networks and then asked the initial participants to suggest other participants for the study. The participants' ages ranged from 35 to 60 years of age, and their experience in smart cities ranged from five to ten years. The participants held either a master's or a doctoral degree, and each interview lasted, on average, 60 min. The interviews included semi-structured questions that were inspired by the TRI 2.0 qualitative interview questions, while adapting the questions to the context of SCS and the objectives of this research. The first and second questions aimed at identifying the unique characteristics of SCS and examples of existing services and envisioned ones. The third and fourth questions aimed at discovering the key enablers and inhibitors affecting the adoption and continued usage of SCS. In each interview, which were conducted online using the WebEx application, the participant was asked to rely on their experience to answer the following questions:

1. In your expert opinion, what are the unique characteristics of smart city services, as compared to regular services?
2. Give examples of existing or future smart city services envisioned in the UAE and worldwide.

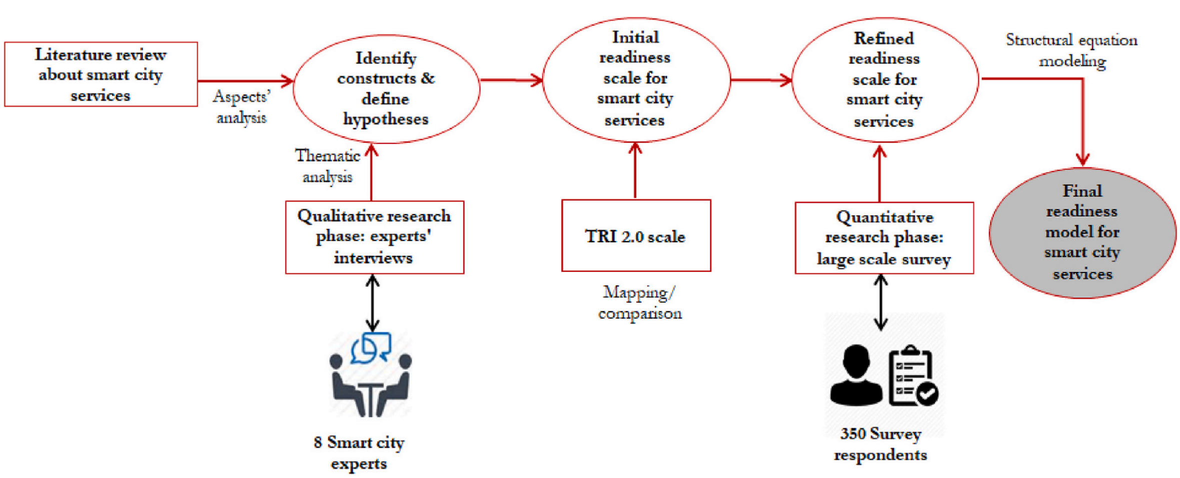

Fig. 1. Overview of mixed method research methodology employed.

3. What would motivate the adoption and continuous use of future smart city services?
4. What would make people hesitant to adopt and continuously use future smart city services?

This phase helped to produce relevant data that helped us identify themes related to the enablers and inhibitors of the adoption and continued use of future SCS. The interviews were recorded and transcribed, and thematic analysis [64] was used to analyze the data with the aim of identifying key categories that revealed patterns based on both deductive ('a priori) and inductive (emerging) themes. This deductive-inductive method analysis method helped to understand the "what and who" nature of the current phenomenon [87,88]. In particular, the semi-structured interviews helped to identify emerging themes and supplementary contextual information to the overarching themes identified in the literature. Thus, the qualitative research helped to draw out key emerging themes that enriched the existing themes, which then yielded a conceptual model (see Fig. 2). Table 1 highlights some of the interviewees' responses concerning those three new dimensions.

To ensure the reliability and validity of our qualitative data, we generated suitable codes from the transcribed data and compared the data collected from the eight participants, until information saturation/ convergence was reached. Specifically, all respondents were asked the same questions and their answers were carefully recorded and transcribed. To analyze the data, we used thematic analysis with using NVivo v.12. We chose thematic analysis because it is a commonly used and highly flexible approach that provides theoretical freedom to different qualitative data [89]. More specifically, to identify the themes, we adopted Braun and Clarke's [89] six-step framework that includes, familiarizing yourself with the data, generating initial codes, searching for themes, reviewing themes, defining themes and then writing-up the results. In doing so, we followed the deductive-inductive approach discussed above and moved back and forth throughout these steps, not necessarily in a liner way in order to identify the relevant themes. Thus, answers were analyzed, coded, and compared to identify common insights and quotes, where were used to derive our key themes. Finally, to avoid the three common threats related to data validity (i.e. researcher bias, reactivity, and respondent bias), we followed a strategy of coder triangulation and kept an audit trail. The main themes that emerged from the thematic analysis aligned well with the existing four TRI 2.0 dimensions (i.e., optimism, innovativeness, discomfort, and insecurity). Moreover, three new themes/dimensions emerged from our qualitative data, namely: 1) Empowerment (as an enabler), 2) Mistrust (as inhibitor), and 3) Legal considerations (as inhibitor).

In addition to the identified themes, the qualitative research phase allowed us to come up with a revised definition of SCS, as well as an identification of their unique characteristics. In this work, we define *smart cities services as services that focus on the seamless integration of policies, processes, and data to serve a city's population, allowing the citizens to be prosperous and be happy*. Some of the identified unique characteristics of SCSs include those that:

1. can be accessed anytime, anywhere, using the Internet and mobile technologies.
2. can anticipate and predict the user needs.
3. Are offered, operated, and financed sustainably.
4. Are affordable and save time, effort, and money to citizens.
5. Are conducted end-to-end electronically.
6. Are easy to use and are offered through integrated multiple channels (e.g., by phone, online, by walk-in, through different service providers).
7. Minimize the users' manual interactions with service providers.
8. Offer advanced electronic payment gateways, mobile payments, and mobile wallets.
9. Rely on seamless data exchange between different service providers.

3.2. Theorizing the intention to continue using SCS

Based on the themes (and subthemes) identified in the qualitative research phase, we developed a conceptual research model investigating the relation between enablers, inhibitors, users' satisfaction, discomfort, and continuous usage intention towards smart city services. Fig. 2 depicts this model, in which hypotheses focusing on the mediated paths will be tested. The aim of this work is to use the experience of users with the current smart services as a way to assess their readiness and intention to use the more advanced/elaborate versions of those services. Examples of existing SCSs in the UAE include: Smart parking, Dubai now, Salam electronic medical records, S'Hail, Green building solutions, Dubai now, E-Dirham, Smart identity, Smart Nol Car, RTA eWallet, and Makani. Among others, SCSs have several benefits such as: (i) in the transport sector, smart city applications help cities to manage traffic flows, reduce congestion and carbon emissions [90], (ii) in the healthcare sector, they help cities to control the demand and supply of health service resources and facilities [91], (iii) other cities have optimized

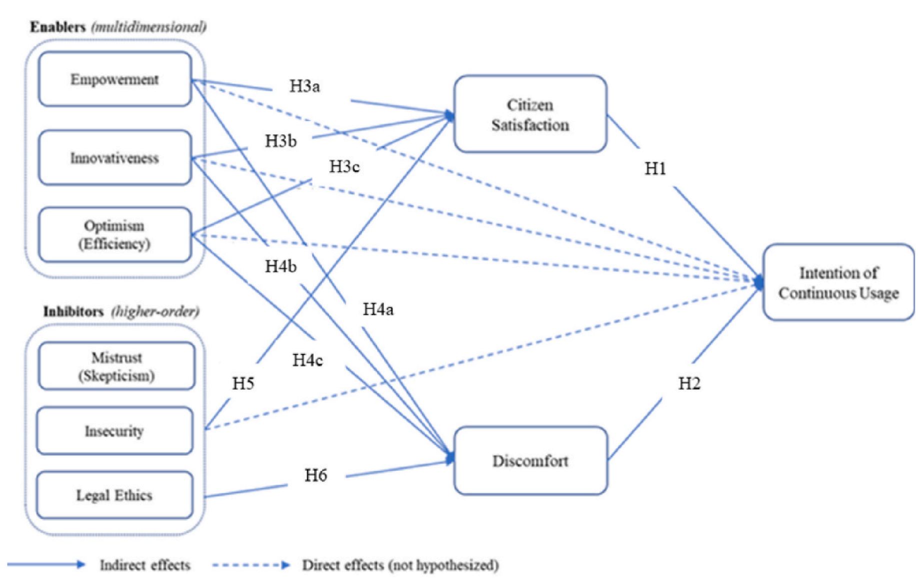

Fig. 2. Conceptual research model.

Table 1
Examples of responses from the qualitative research phase with a focus on the new dimensions identified.

	Sub-theme	*Selected quote*
Empowerment	The users' ability to control the collection of their usage history	*… they collect information non-invasively without asking the users to enter the data …*
	The users' ability to control data collected about them	*The involvement in the process means increased visibility in the process and increased confidence and trust as well*
	The users' control over how their personal information is used	*… has to ensure the privilege is only for those who have the right, or I give them the right to use this data*
	Users' choice to be directed to another system …	*in terms of services that the citizen gets in trusting the third party, I think that is still an issue …*
	Collaboration with users to co-create the service	*… users are able to connect with each other in order to create their own service for their profit or for personal gain*
Mistrust	Trust will be built gradually when interacting with the service provider	*Trust is a combination of different parameters: privacy, transparency, reputation, regulations, and it will take time.*
	Image and reputation affect trust in the smart service provided	*The perception and expectation of what smart city should be vary greatly amongst the user base; I mean, obviously, there are issues around trust.*
	Personal information might not be treated with confidentiality	*Many people perceive it as a breach of privacy as they are being monitored.*
	SCS providers hide important information from users	*… the matter of trust that will come up if any personal info is being used*
	Terms and conditions associated with various SCS are hard to track	*It is important to trust this type of government with this kind of terms and conditions, and I think, reasonably, over time, you've seen that the government has improved.*
	Payment methods are not secure	*Again, the cost of providing smart services to a certain extent comes with your having to give up your perceived sense of security.*
Legal considerations	The lack of a regulatory framework may hinder adoption	*SCS doesn't have enough regulations and rules to protect the users. smart services and the regulations that exist nowadays in UAE is not enough and gaps that may arise.* *But again, the cost of providing smart services to a certain extent comes with your having to give up your perceived sense of privacy or security.*
	Weak authentication features, potentially leading to security breaches.	*The SCS is not going to be the service that is provided directly to the customer who are the users of their service but will also be able to gather information from other providers that might lead to security breach* *ultimately, as I said earlier, sharing is a virtual quality; you have to share information. There is no point describing yourself as smart if all you know is one aspect of the information.*
	Change of terms without consent	*… transparency is very important when the terms and conditions of services change, in order to build trust with users.*

these applications to manage waste collection and waste processing [92], and (iv) they build resilient cities by helping with disaster management such as identifying and responding to natural and man-made crises [93].

3.2.1. Direct effects of citizen satisfaction and discomfort on continuous usage of SCS

Hypothesis 1. Although adoption is a fundamental step of success, SCS provisioning, investigating post-adoption behavior is just as important to understand if citizens intend to continue using these services. The first main driver of post-adoption intention was identified to be **citizens' *satisfaction***–the degree to which citizens' needs and expectations are satisfied. Indeed, satisfaction has previously been linked to the successful adoption of technology-enabled services [59–61]. Chen et al. [94] have also shown that user satisfaction is relevant for the future intention to use those services, a relation that was also confirmed in Refs. [18,62]. In contrast, the authors in Ref. [14] have shown that citizens' dissatisfaction, which is triggered by the inability of service providers to assess and attend to people's needs adequately, is a cause for low services' adoption. We, therefore, hypothesize that citizens' satisfaction has a significant positive impact on their intention to use future SCS continuously.

H1. Citizens' satisfaction has a significant positive impact on citizens' intention of SCS continuous usage.

Hypothesis 2. **Discomfort** reflects a feeling of being overwhelmed by technology and not having control over it [60]. With the advent of more sophisticated and more complex smart services, the general public may feel that those services are not designed to be used by ordinary people, offer complex interfaces, and are reserved for technically savvy individuals [95]. They may even be overwhelmed by communication with technical support teams or complex services' manuals [96], thus accentuating the sense of lack of technical skills of the general public to effectively use those advanced services. Another aspect associated with the discomfort dimension is being overwhelmed by the rapid change/update of SCS and the resistance to innovation and change [97,98]. Thus, we hypothesize that discomfort has a significant negative impact on citizens' intention to use future SCSs continuously.

H2. Discomfort has a significant negative impact on citizens' intention of SCS continuous usage.

3.2.2. Mediating effects of citizen satisfaction on the relationship between enablers and continuous usage of SCS

Hypothesis 3. Along with the TRI 2.0 two enablers of technology adoption (i.e., optimism and innovativeness), we are proposing a third enabler that is tailored to the characteristics of smart services, namely: **empowerment**. As can be noted, the word "empowerment" comes from the word "empower", meaning to give people power (in our context, 'control'). The literature agrees that empowerment has several conceptualizations and has been operationalized differently and has three types that include community, structural and psychological [see 98 for more details]. In this study, we focus on the psychological empowerment, which reflects individual intrinsic motivation towards a certain task [99]. Moreover, according to Han et al. [100], psychological empowerment is multifaceted and cannot be captured by one concept; thus, it is reflected by four dimensions: 'meaning, competence, impact and self-determination'. In our study, we focus on the self-determination dimension, which refers to one's perception of autonomy and the feeling of control in a specific environment [100]. Thus, to empower smart city citizens is to give them control over certain aspects of the SCS they are using. If the SCS rely heavily on autonomous operations, empowered citizens might benefit from a few checkpoints along the way, to decide when and how personal information can be used by service providers [101]. For example, the Internet of Things (IoT) services should provide users with individual control over data collection and processing to overcome privacy issues. However, power over one's data is not the only concern, as users also value the possibility to choose when and how services (especially those with more impact over comfort and habits) will be activated. For example [102], studied smart meter adoption in Austria and demonstrated that freedom of choice to use a device, overriding automated load shifts, was a feature that consumers considered very important for the intention of adoption. Considering that loss of control is a source of reservations and unease towards service usage [103], empowerment may influence citizens' satisfaction to adopt and continuously use SCS [104,105]. This suggests the following hypothesis:

H3a. Citizen satisfaction mediates the relationship between empowerment and intention of SCS continuous usage.

Another major motivator of technology adoption in the TRI 2.0 model is ***innovativeness***–the innate tendency of pioneering and leading the way for technology adoption, effectively influencing others to follow [21]. Innovativeness has previously been shown to positively influence usage intention in IT [106], as well as user experience with technology consumption–in this case, using positive reinforcement of users' affinity with technology [107]. Because of their higher propensity of using novel technologies, innovators are a valuable user group to engage in SCS development. Thakur and Srivastava [108] argue that companies should actively seek out innovators as they can help in the diffusion of technology as well as provide valuable feedback for its improvement. These innovative users see the usefulness in shaping and using new technologies through input provision. For instance, the study presented in Ref. [109] found that innovators are more prone to participating in web surveys. The positive influence exerted by innovativeness over user experience with technology-enabled services was found to influence user satisfaction directly [94], and thus can have an indirect impact on continued usage. Therefore, we hypothesized that:

H3b. Citizen satisfaction mediates the relationship between innovativeness and intention of SCS continuous usage.

Another technology adoption motivator from the TRI 2.0 model is ***optimism*** – i.e., the belief that technology offers improvements to quality of life in the form of greater efficiency, flexibility, and control [21]. This may be achieved, for instance, using data gathering and processing capabilities that would enable SCS to learn from the user's previous interactions to anticipate his/her future choices needs. Moreover, SCS may offer improved and customized interactions to users by adapting their behavior to certain contextual parameters (e.g., time, location). Such capabilities could lead to more user satisfaction, as highlighted in Refs. [110,111]. Furthermore, scholars have shown that service personalization leads to transaction cost reduction and emotional factors that contribute to the perception of usefulness [112]. The reduction of users' efforts when interacting with new technology and services was shown to have a significant impact on their intention to continue to use those services [113]. Thus, we hypothesize that optimism (operationalized in the form of efficiency reflects one of the distinguishing characteristics of SCS) contribute to citizens' readiness to adopt and continuously use future smart services.

H3c. Citizenship satisfaction mediates the relationship between optimism and intention of SCS continuous usage.

3.2.3. Mediating effects of discomfort on the relationship between enablers and continuous usage of SCS

Hypotheses 4: Prior literature has conceptualized ***discomfort*** as an inhibiting factor that inversely influence citizens' adoption and continuous usage of future of SCS [60]. In other words, consumers with high levels of discomfort tend to associate new tech-based services with complexity, thereby resulting in disappointment and frustration and eventually restraint to adopt such new technology [62]. Thus, discomfort represents a perception and feeling of being overwhelmed by new innovation that deters technology readiness [21]. As such, when one feels lack of control and confidence in new technology, insecurity or lack of trust can trigger discomfort that in turn leads to skepticism towards the usage of new technology [60]. Research also shows that there are more context-specific attitudes that mediate the link between technological readiness and behavioral intention [114]. This is because 'technology is paradoxical' and can engender multiple (both positive and negative) attitudes that impact consumer responses to technology [114]. As a result, we posit discomfort (i.e., negative attitude) as a mediator in this context of SCS, such that, we expect the enabling factors to reduce the discomfort levels that in turn positively influence the adoption and continuous usage of future smart services. Indeed, in the assessment of the TRI 2.0 scale validity, it was shown that there exists a negative correlation between enablers and inhibitors' pairs – with a correlation coefficient of -0.32 between optimism and discomfort, and a coefficient of -0.40 between innovativeness and discomfort [24]. Moreover, studies have shown a relationship between personality traits such as discomfort and users' expectations and long-term adoption of technologies [115]. Unlike other models that consider discomfort as an independent TR variable, we hypothesize that discomfort is rather accentuated or reduced by the TR enabling and inhibiting factors, and can serve as mediator to continued usage. Examining discomfort as a mediator, potentially, addresses extant literature that presents fragmented views regarding the role of discomfort in technology adoption research [see, 116, 117]. Thus, we define three hypotheses related to the three enablers (empowerment, innovativeness, and optimism), continued usage and discomfort as mediator.

The first hypothesis focuses on the relationship between empowerment and the intention of continuous usage, mediated by discomfort. Somerville [118] defines empowerment as any process where people can gain increased control over their lives. Welch shows that adopting government services enhances the communication and collaboration between government and citizens, but not necessarily lead to an intention of continuous usage [119]. The results presented in Ref. [119] show that empowerment influences the intention to use services, while [119] suggests that citizens' empowerment is critical for their engagement with and adoption or e-government services. No research has been conducted on the mediating effect of discomfort on the relationship between empowerment and continuous usage intention, in the context of smart cities. Addressing this gap, we hypothesize that:

H4a. *Discomfort mediates the relationship between empowerment and intention of SCS continuous usage.*

The second hypothesis addresses the mediating effect of discomfort on the relationship between innovativeness and continuous usage intention. Innovativeness was first addresses by Agarwal and Prasad [120] in their technology acceptance model, in which personal innovativeness in information technology (PIIT) was identified as personality trait that influences technology adoption behavior. The authors argued that individuals with high PIIT (i.e. those willing to try any new technology) are expected to develop more positive beliefs about new technologies. Lu et al. [121] tested the impact of personal innovativeness, among other factors, on the adoption of wireless Internet services, and their results confirmed the positive impact of innovativeness on adoption intention. Meanwhile, Thakur and Srivastava's findings revealed that innovativeness has an important impact on the intention to adopt mobile payments in India. A recent study by Singh et al. [122] emphasizes the effect of innovativeness on the intention to adopt mobile wallet services. Consequently, innovativeness increases citizens' willingness to take risk with respect to new emerging services, and lead them to exhibit less discomfort and a stronger intention to use such services [123]. In line with those ideas, we propose the following hypothesis:

H4b. *Discomfort mediates the relationship between innovativeness and intention of SCS continuous usage.*

The third hypothesis addresses the mediating effect of discomfort on the relationship between optimism and continuous usage intention. Technological optimism is defined as "a positive view of technology, and a belief that it offers people increases control, flexibility, and efficiency"

[24]. Optimistic citizens tend to accept new situations and are more willing to use new technologies [121]. Furthermore, such individuals tend to see more benefits in emerging technologies and worry less about their negatives [62]. For instance, Flavian et al. [124] examined how banking customers' technology readiness affects their intention to use AI-based investment services (i.e. Robo-advisors). The results indicate that customers' optimism lead to an increased intention to use Robo-advisors. Bult et al. [30] argued that highly optimistic people find learning new technologies rewarding, while customers with a high degree or discomfort when using new solutions believe that technology is too complicated for them [125]. Therefore, we hypothesize that:

H4c. *Discomfort mediates the relationship between optimism and intention of SCS continuous usage.*

Hypothesis 5. Beside motivators, the TRI 2.0 models also define constructs that inhibit technology adoption namely: mistrust, insecurity, and legal considerations. **Insecurity** is the general wariness about technology and doubt about its ability to work correctly [21]. Concerns related to authentication features, for instance, are highlighted in the study presented in Ref. [103]. This study shows that the increasingly complex environment that supports smart services creates a scenario where a single weak link in the value chain can render personal data accessible to third parties – *via* weak privacy agreements or vulnerabilities to attacks. Although data privacy is an important issue, insecurity also manifests itself in institutional and legal dimensions. In that respect, the lack of legal and regulatory frameworks and the volatile nature of SCS terms and conditions are a cause for concern [126,127]. To understand the construct of ***mistrust***, one must consider that trust can influence satisfaction with technology-enabled services [128]. This influence is so strong that even well-functioning services can yield negative experiences when users feel distrustful or anxious towards technology or service providers [129]. Due to the inherent collection of personal data in smart services, the intentions behind its collection and the very provision of SCS can offer a fertile ground for mistrust. Therefore, providers must build a good reputation by continuously and progressively demonstrating to users the benefits and value of SCS [103]. In a context where one's personal data is in the hands of service providers, experienced users (even more so) develop trust issues, which must be overcome to guarantee continued usage intention [45]. **Legal considerations** entail the legal frameworks required to regulate the ethical aspects associated with smart services' operations, such as data confidentiality, sharing of information between different entities, obtaining appropriate consent from users, and ensuring freedom and autonomy to users [130]. In this study, we operationalized **inhibitors** as a **higher-order construct** comprising of these three inhibiting factors (i.e. insecurity, mistrust, and legal considerations). Furthermore, we considered that those inhibitors have an impact on satisfaction [131], which in turn impacts intention of continuous usage. Considering the above concerns and their influence on the adoption and continuous usage of future service, we hypothesize that:

H5. Citizen satisfaction mediates the relationship between inhibitors (higher-order construct comprising of mistrust, insecurity, and legal considerations) and intention of SCS continuous usage.

Hypothesis 6. Discomfort is associated with a feeling of lack of control and overwhelm by new technologies. In Parasuraman's paper, discomfort was found to be a weak TR construct in terms of psychometric criteria, as it represented a set of heterogeneous attributes that are difficult to combine in a single construct [24]. Instead of eliminating discomfort from our model, we argue that discomfort should be considered as a mediating variable not independent TR variable. Indeed, while insecurity, mistrust, and ethical implications are clear inhibitors, discomfort is more subtle as an emotion representing the process or conduit leading to less adoption or discontinued usage. The impact of discomfort on consumer usage patterns has been shown in Ref. [62]. In this work, we are proposing the idea that the inhibitors (such as insecurity, mistrust and ethical considerations) trigger a certain level of discomfort, which then reduces one's chance of adopting and continuing to use the SCS [132,133]. The following hypothesis is therefore proposed to capture this idea:

H6. Discomfort mediates the relationship between inhibitors (higher-order construct comprising of mistrust, insecurity, and legal considerations) and intention of SCS continuous usage.

3.3. Study 2: quantitative research phase

To test the hypotheses presented in the previous section and develop and validate a readiness assessment scale for SCS, we relied on conclusive quantitative research, which involved a survey that utilized structured/closed-ended responses and a large sample size to allow researchers to produce results that are more representative and thus, generalizable to the population. In this phase, we targeted the users of SCS (i.e., citizens) living in the UAE – the most prominent technology hub in the MENA region, according to the CIA World Factbook published in 2019. According to the UAE government's official portal, the country aims at transforming Dubai into a leading global smart city over the coming few years. Moreover, Dubai and Abu Dhabi (the UAE capital) led the Middle East and the North African regions in a new global ranking (the IMD Smart City Index[1]) in 2021, beating technologically advanced cities such as Shanghai and Tokyo in implementing smart city services. The IMD Smart City 2021 index placed Dubai in the 29th spot and Abu Dhabi in the 28th spot, out of 118 cities in a global ranking of smart cities showing an overall significant jump for UAE in the global smart-city ranking. Based on the above, we believe that the use of the UAE as a research setting in our research is relevant and significant.

Our survey instrument was developed based on findings from the literature, the thematic analysis results, and hypotheses obtained from the qualitative research phase. The proposed scale is an extension of the TRI 2.0 scale [24], where new items where added and existing items were modified, to address the unique characteristics of smart city services. Furthermore, the scale drew inspiration some concepts proposed to measure citizens' satisfaction and intention of continued usage presented in Refs. [49,134]. From the TRI 2.0, the four original dimensions (i.e. optimism, innovativeness, discomfort, and insecurity) where kept and updated to suit the unique characteristics of smart city services, while three new dimensions inspired by the findings from our qualitative research findings were added. Table 2 depicts our extended technology readiness scale that was designed by adapting and extending the original TRI 2.0 dimensions (i.e. optimism, innovativeness, discomfort, and insecurity) with new items, while adding three new dimensions (empowerment, mistrust, and legal considerations). The rationale behind this design is as following:

- In the original TRI 2.0 questions related to innovativeness and insecurity, the word "Technology" was replaced by "Smart city services" for a more defined and clearer context.
- Ten new items were added to two existing TRI 2.0 dimensions (optimism and discomfort). These emerged as important themes from our exploratory qualitative research phase, and were added to reflect aspects that are particular to SCS.
- Three new dimensions were added based on findings from the qualitative phase, namely: 1) Empowerment, and 2) Mistrust, and 3) Legal considerations. These dimensions were highlighted by the interviewed experts as important to the context of SCS.
- The discomfort dimension is conceptualized as a mediating variable in our study and strengthened with 6 additional items that reflect unique characteristics of smart services that may cause discomfort,

[1] https://www.planbe.com.gr/news/smart-city-index-2021.

Table 2
Smart city services' technology readiness scale.

Code	Scale item wording	*TRI 2.0/ New item*	References
OPTIMISM			
OPT 1	Smart city services anticipate my future needs based on my previous interactions	New item	[47,48]
OPT 2	Smart city services make automatic decisions based on my situation	New item	[97]
OPT 3	Smart city services connect me to multiple systems in the city	New item	[26]
OPT 4	I find it convenient to communicate with smart city service providers	New item	[26]
INNOVATIVENESS			
INN 1	Other people come to me for advice on new smart technologies	TRI 2.0	[24]
INN 2	In general, I am among the first in my circle of friends to acquire new smart technology when it appears	TRI 2.0	[24]
INN 3	I can usually figure out new smart city services without help from others[a]	TRI 2.0	[24]
INN 4	I keep up with the latest smart technology developments in my areas of interest	TRI 2.0	[24]
EMPOWERMENT (New dimension)			
EMP 1	I want to choose whether smart city services store my usage history[a]	New item	[40]
EMP 2	I want to decide whether to provide my personal information to smart city service providers	New item	[40]
EMP 3	I want to have control over how smart service providers use my personal information	New item	[41]
EMP 4	I want smart city services to ask me before directing me to another system or website	New item	[41]
INSECURITY			
INS 1	People are dependent on smart city service providers to do things for them	TRI 2.0	[24]
INS 2	I do not feel confident doing business with a place that can only be reached online	TRI 2.0	[24]
INS 3	Too many smart services distract people to the harmful point	TRI 2.0	[24]
INS 4	Smart city services lower the quality of relationships by reducing personal interactions	TRI 2.0	[24]
LEGAL CONSIDERATIONS (New dimension)			
LEG 1	The lack of a regulatory framework controlling smart city services may hinder their adoption.	New item	[51,52]
LEG 2	Some smart city services have weak authentication features	New item	[42]
LEG 3	Smart services change their terms and conditions, without their users' consent	New item	[102]
MISTRUST (New dimension)			
MIS 1	My personal information might not be treated with confidentiality by smart service providers	New item	[54,55]
MIS 2	Smart city services hide important information from users (e.g., not showing the seat number in cinema ticket booked online)	New item	[54,55]
MIS 3	Terms and conditions associated with smart city services change frequently and are hard to track	New item	[54,55]
MIS 4	Smart city services payment methods are not secure	New item	[54,55]
DISCOMFORT			
DIS1	When I get technical support from a provider or a high-tech product or service, I sometimes feel as if I am being taken advantage of by someone who knows more than I do	TRI 2.0	[24]
DIS2	Technical support lines are not helpful because they don't explain things in terms I understand	TRI 2.0	[24]
DIS3	Sometimes, I think that technology systems are not designed for use by ordinary people	TRI 2.0	[24]
DIS4	There is no such thing as a manual for a high-tech product or service that's written in plain language	TRI 2.0	[24]
DIS5	I find it difficult to keep up with the latest smart services.	New item	[117]
DIS6	Smart city services pose access challenges in using them (e.g. they are running on small screens and using touch keyboards, don't have access support for disabled people).	New item	[116,117]
DIS7	New smart city services are not compatible with consumers' existing practices and habits.	New item	[117]
DIS8	Due to the regular updates of smart systems, the user experience can change dramatically.	New item	[117]
DIS9	Smart city services are costly.	New item	[116,117]
DIS10	Smart city services have complex user interfaces.	New item	[115]

[a] These two items were dropped during EFA due to low factor loadings.

such as: access challenges, resistance to change/innovation, changing user experience, associated cost, and complex interfaces.

- The new dimensions and items added were all supported by references from the literature (see references column in Table 2).

The questionnaire was designed using a 5-point Likert scale (strongly disagree = 1 to strongly agree = 5), and was conducted online using the English Language. We opted for a five-point scale, because it is relatively easier for respondents to understand, is ideal for a larger sample size, and produces better distribution of data [24]. A link to the questionnaire was emailed to 2350 UAE residents, out of which a total of 600 completed responses (26%) were received, while 350 useable responses (15%) were analyzed for this research. Table 2 provides the measures used in this study.

The sample population of this study consisted of two target groups that were selected using both types of sampling design: non-probability and probability sampling [135,136]. The first group was identified using non-probability sampling in which the researchers used a convenience sampling to target university students in the UAE. This helped to select a sample that represents millennials and generation Z, whom when combined represent the biggest consumers' category in the region and the typical users of smart services. For the second group, probability sampling design was used to select a stratified random sample using LinkedIn contacts. A random sampling technique was used to ensure a representative sample that represents different UAE social strata in the study. Table 3 summarizes the demographic characteristics of the pool of respondents.

As shown in Table 3, the pool of participants was gender-balanced, with about 44% male respondents and 56% female respondents. Most respondents (≈54%) were aged between 18 and 24, while about 24% of respondents were aged between 25 and 34, thus placing the majority of the respondents in the millennials and generation Z categories. Since those younger generations represent the majority of the users of future smart services and will constitute the most significant categories of consumers in the near future, their adequate representation in this study is essential and will provide significant insights. Likewise, most respondents fell in the 'explorer' category, a characteristic that is associated with the millennial's generation. In terms of nationality, 85% of the participants were non-Emirati, and 15% were Emirati. This reflects the natural composition of the UAE population, with a majority of expatriates. More than half of the respondents had a bachelor's or master's degree, thus making them relatively tech-savvy. Finally, the majority of the respondents consider themselves as explorers and pioneers (about 82% when combined). According to the diffusion of innovation theory [114], explorers and pioneers coincide with the innovators and early adopters' psychological profiles, which embrace innovation and change readily, and do not require any prior experience or evidence to use new technologies.

Table 3
Participants' Demographic characteristics.

Age	%	Education	%	Income	%	Technology Readiness	%
18–24	54.4%	High school	18.4%	Less than 10,000	59.3%	Explorer	65.1%
25–34	23.5%	Bachelor's degree	54.7%	10,000–20,000	15.7%	Skeptic/Doubtful	10.4%
35–44	13.3%	Master's degree	21.1%	20,000–30,000	14.3%	Pioneer	17.1%
45–54	7.7%	Doctoral degree	4.8%	30,000–40,000	4.5%	Hesitator	5.3%
55 and over	1.1%	Professional certificate	1%	More than 40,000	6.2%	Avoider	2.1%
Gender	**%**	**Nationality**	**%**				
Male	44.3%	Emirati	14.8%				
Female	55.7%	Non-Emirati	85.2%				

4. Data analysis and proposed model

To test the proposed research model, this research used the covariance-based structural equation modeling (SEM) in AMOS v.26. The covariance-based SEM approach is widely used [see 136] and related recent research also published in *Technology in Society* by Kusumastuti et al. [137] also tested its structural model using SEM in AMOS. SEM is an effective approach as it helps to reduce standard errors due to the simultaneous estimation of all parameters in a single model [138] and not sequentially as is the case in regression analysis that analyze only one layer of linkages between independent and dependent variables at a time [139]. Most importantly, in line with our research model, SEM provides the state-of-the-art approach to testing for mediation effects among constructs, especially when multiple items have been measured to capture any of the focal constructs [140]. SEM is also considered the most natural choice for determining mediation structures [138].

4.1. Measurement model

The next step in the analysis is to ensure that the constructs are valid and reliable as this is particularly important to facilitate hypothesis testing using SEM. In line with recommendations by Ref. [141], we conducted some preliminary tests to assess whether the data distribution met the assumptions and requirements of multivariate analysis. To test for multicollinearity, we ran multiple regression tests, which showed that all variance inflation factor (VIF) scores were below the recommended cut-off of 10, suggesting that multicollinearity is not a major concern in this study [142]. Then, we conducted reliability tests using the Cronbach's alpha, and composite reliability measures.

As shown in Tables 4 and 5, all three measurements were above the recommended 0.6 threshold, indicating that the constructs were reliable. Next, given that we utilized items based on existing literature as well as added new items based on the exploratory qualitative research discussed above, exploratory factor analysis (EFA) was conducted to identify the underlying factor structure and the results showed that all items loaded well onto their respective constructs. Thus, unidimensionality was established through EFA, that is, the measured variables were explained by only one underlying construct as this is important when more than two constructs are used [143]. As shown in Table 2, a few items that did not load well and/or had large cross-loadings were removed from subsequent analysis.

Validity measures are tested using average variance extracted (AVE), Heterotrait-Monotrait ratio of correlations (HTMT), and confirmatory factor analysis (CFA). As recommended in Ref. [144], the AVEs of all constructs were above 0.5, which means that the amount of variance that was captured by a construct due to measurement error was not significant. Discriminant validity was assessed by calculating the HTMT ratio, and as recommended in Ref. [145], none of the HTMT ratios for the paired constructs were greater than 0.90, which means that discriminant validity was established between the reflective constructs. CFA was used to test how well the measured variables represent the number of constructs and the results revealed that all criteria were met and showed good fit based on the following indices: $\chi^2/\ df =\ 1.939$,

Table 4
Construct validity and reliability.

Items	Loadings	*Cronbach's alpha (α)*
Continuous Usage		.852
CTU 1	.808	
CTU 2	.801	
CTU 3	.822	
Empowerment		.800
EMP 1	.641	
EMP 2	.894	
EMP 3	.765	
Innovativeness		.813
INN 1	.775	
INN 2	.810	
INN 3	.732	
Optimism		.754
OPT 5	.703	
OPT 6	.698	
OPT 7	.731	
Insecurity		.800
INS 1	.639	
INS 2	.702	
INS 3	.784	
INS 4	.658	
Legal considerations		.739
LEG 1	.750	
LEG 2	.638	
LEG 3	.689	
Mistrust		.784
MIS 1	.622	
MIS 2	.698	
MIS 3	.792	
MIS 4	.681	
Satisfaction		.888
SAT 1	.822	
SAT 2	.884	
SAT 3	.850	
Discomfort		.877
DIS 1	.735	
DIS 2	.746	
DIS 3	.714	
DIS 4	.743	
DIS 5	.782	
DIS 6	.716	

$\chi^2/df = 1.939, RMR = .048,\ IFI = .933,\ CFI = .933,\ TLI =\ .923, RMSEA,\ = .050$

$RMR\ = .048,\ IFI\ = .933,\ CFI\ = .933,\ TLI\ =\ .923, RMSEA\ \ = .050$.

Common method bias was likely in this study since we relied on a self-administered survey to assess all the constructs in our framework. Thus, we employed both procedural and statistical analysis to minimize and address potential common method bias. First and procedurally, double-barreled questions were avoided, and the items were dispersed throughout the survey to minimize self-report validity. Second, a Harman's one-factor test was employed by subjecting all measurement items to a single principal component factor analysis with an unrotated solution [84]. Lastly, as recommended by Ref. [146], variance inflation factors (VIFs) were generated for latent variables in the measurement

Table 5
Inter-construct correlations and discriminant validity.

	CR	AVE	MSV	1	2	3	4	5	6	7
Optimism	0.754	0.505	0.434	1						
Innovativeness	0.816	0.598	0.323	0.568	1					
Satisfaction	0.888	0.727	0.421	0.586	0.442	1				
Empowerment	0.815	0.598	0.424	0.513	0.280	0.403	1			
Continuous Usage	0.852	0.657	0.434	0.659	0.550	0.649	0.651	1		
Inhibitors	0.944	0.850	0.738	0.054	0.060	0.006	0.021	0.033	1	
Discomfort	0.879	0.547	0.738	0.021	0.036	−0.040	−0.179	−0.124	0.859	1

Note: All correlations are significant at 0.01 level; CR = composite reliability; AVE = average variance extracted; MSV = maximum shared variance.

Table 6a
Path analysis.

H	Direct effects			β	b	S.E.	t	p	Result
H1	Citizen satisfaction	→	Continuous usage	.303	.254	.048	5.315	***	Supported
H2	Discomfort	→	Continuous usage	−.254	−.194	.098	−1.985	.047	Supported
–	Empowerment	→	Citizen satisfaction	.142	.168	.075	2.232	.026	–
–	Innovativeness	→	Citizen satisfaction	.166	.155	.065	2.368	.018	–
–	Optimism	→	Citizen satisfaction	.421	.511	.107	4.766	***	–
–	Empowerment	→	Discomfort	−.250	−.324	.067	−4.831	***	–
–	Innovativeness	→	Discomfort	−.005	−.005	.055	−.099	.921	–
–	Optimism	→	Discomfort	.106	.140	.087	1.619	.105	–
–	Inhibitors	→	Citizen satisfaction	−.031	−.036	.059	−.623	.533	–
–	Inhibitors	→	Discomfort	.859	1.105	.103	10.766	***	–
–	Empowerment	→	Continuous usage	.323	.321	.065	4.921	***	–
–	Innovativeness	→	Continuous usage	.216	.169	.046	3.687	***	–
–	Optimism	→	Continuous usage	.186	.189	.080	2.355	.019	–
–	Inhibitors	→	Continuous usage	.219	.199	.114	1.747	.081	–

***p < 0.001; significant at .05 level; n = 350; β = standardized; b = unstandardized; SE = standard errors; [−] = not hypothesized.

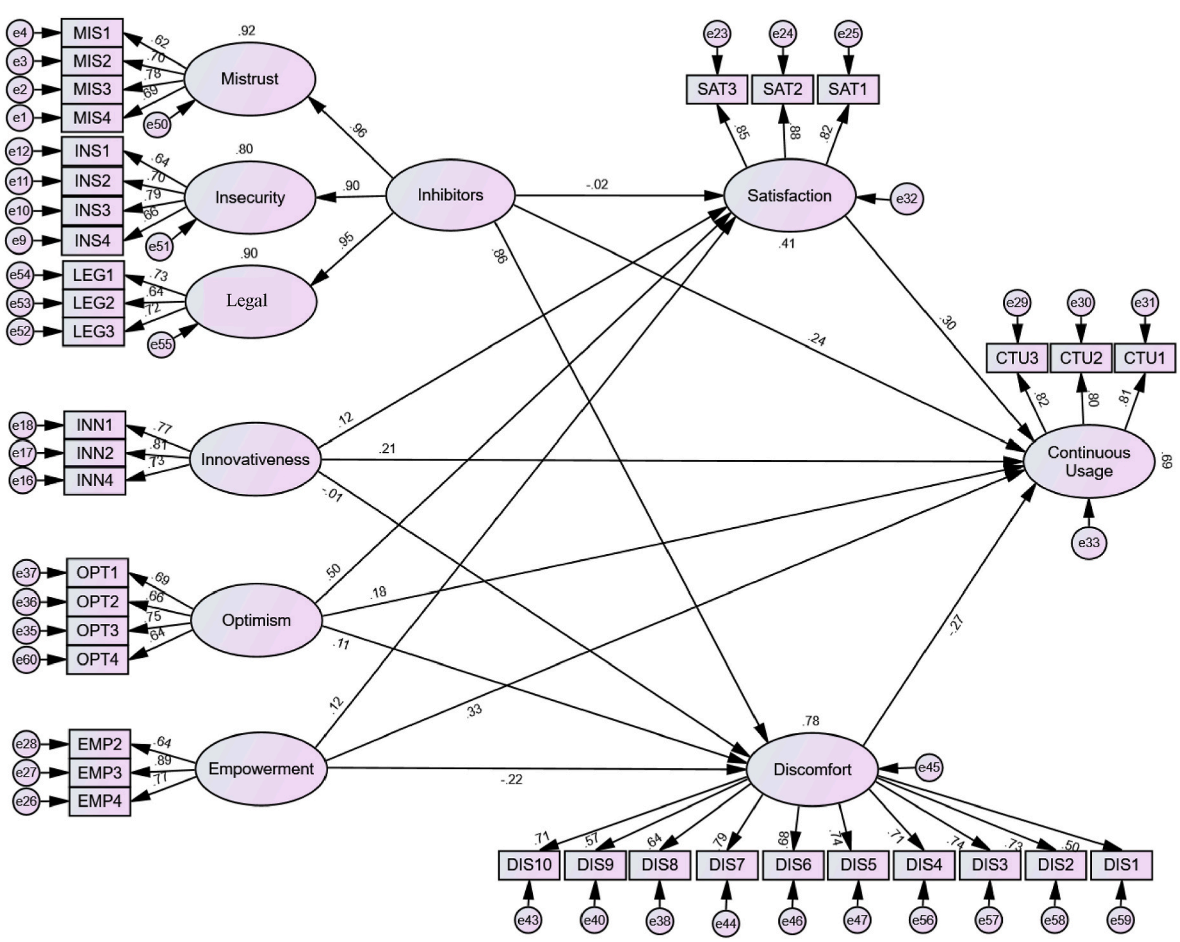

Fig. 3. Proposed model of citizens' technology readiness in the context of smart city services.

model. All inner values were less than 3.3, indicating insignificant pathological collinearity and confirming that the model was not contaminated by common method bias. Overall, these tests suggest that the results of this study were not affected by common method bias.

4.2. Structural model: hypotheses' testing results

As aforementioned, the hypotheses were tested using the SEM tool in AMOS. v26. Fig. 3 depicts our proposed model of citizens' technology readiness in the context of smart city services. The structural model revealed acceptable fit ($\chi2/df = 1.934$, RMR = 0.048, IFI = 0.934, CFI = 0.933, TLI = 0.924, RMSEA = 0.050) as these indices are within recommended cut-off values. The results of the hypothesized paths and the mediation effects are shown in Table 6 (See Table 6a for path analysis and Table 6b for indirect effects).

Based on the obtained model, satisfaction had significant positive effects on continuous usage ($\beta = 0.303$, $p < 0.01$), while discomfort had a negative influence on continuous usage ($\beta = -0.254$, $p < 0.01$), in support of H1 and H2, respectively.

To test for mediation, we used the bias-corrected bootstrap method *via* SEM in AMOS, to estimate direct, indirect and total effects (on 2000 resamples) using a 95% confidence intervals (CIs) [147]. The bootstrap estimation relies on the 95% CIs from the empirical distribution of *a*b* estimates, where the lower limit of the 95% CI is at the 2.5% point on this cumulative distribution, and the upper limit is at the 97.5% point [148]. When interpreting the result, if the CI does not cross zero (0), the indirect effect *a*b* is significant and mediation is established. Otherwise, if the CI includes 0, *a*b* is not significant and mediation hypothesis is rejected. The indirect effects are shown in Table 6b.

The results show significant indirect effects of *empowerment on continuous usage via satisfaction* ($\beta = 0.043$, $p = 0.041$). This is because 95% bootstrap CIs, lower limit (LL) = 0.0007, upper limit (UL) = 0.099 show that the indirect effects did not include zero. Since the direct effect of empowerment on continuous usage is statistically significant ($\beta = 0.323$, $p < 0.01$) this suggests partial mediation effects, in support of H3a. The indirect impact of *innovativeness on continuous usage via satisfaction* is also significant ($\beta = 0.039$, $p = 0.019$), as the 95% bootstrap CIs (LL = 0.012; UL = 0.081) excluded zero. The results confirm H3b as partial mediation as the direct effect of innovativeness on continuous usage is significant ($\beta = 0.216$, $p < 0.01$). The results also show that *satisfaction partially mediates the relationship between optimism and continuous usage* ($\beta = 0.130$, $p < 0.01$), in support of H3c. This is confirmed by the 95% bootstrap CIs (LL = 0.059, UL = 0.248) that did not include zero and significant direct effects ($\beta = 0.186$, $p = 0.019$).

H4 predicted the mediating role of *discomfort on the links between the enablers (empowerment, innovativeness and optimism) and continuous usage*. The results in Table 6b showed no significant indirect effects of all three enablers *on continuous usage via discomfort*. This is because all the 95% bootstrap CIs show that the indirect effects included zero. Thus, H4 is not supported, suggesting that discomfort does not to play a mediating role between the enablers and citizens' continuous usage of SCS.

The results failed to support H5 that predicted significant indirect effects between the *inhibitors and continuous usage via satisfaction* ($\beta = -0.009$, $p > 0.05$), as confirmed by the 95% bootstrap CIs (LL = −0.039, UL = 0.010) that contained zero. However, the results confirm that *inhibitors have a significant mediating impact on continuous usage via discomfort* ($\beta = -0.199$, $p = 0.047$). This is because the 95% bootstrap CIs (LL = −0.402 and UL = −0.033) did not contain zero. In addition, the direct effect between inhibitors and continuous usage is not statistically significant ($\beta = 0.219$, $p > 0.05$). Therefore, in support of H6, the results suggest that discomfort fully mediates the relationship between the inhibitors and continuous usage.

5. Discussion and conclusions

In the context of smart cities, services take on a new light and play a vital role. While traditional e-governments offer remote and digital means of access to services *via* apps, platforms, or bots, a smart government has extensive use of an array of technologies to deliver government services [149,150]. In this sense, SCS employ ICT's potential for data collection, processing, transmission, and analysis to enrich and broaden the possible reach of the said services [28]. This allows services to be delivered in a customized manner to citizens, thereby improving efficiency and quality of life. However, for any of this to happen, citizens need to be ready to adopt the services and their supporting technologies.

Due the dynamic nature of smart cities, technological evolution has caused tension between the positive aspects of smart services and the negative aspect of having to learn and trust new technologies [128]. To adequately quantify if people are ready to adopt new technologies, several models have been proposed, such as the Technological Readiness Index (TRI) version 1.0 [21] and TRI version 2.0 [24]. A study about people's reactions to new technologies was presented in Ref. [89], where the authors identified technology paradoxes (e.g., freedom vs. enslavement, assimilation vs. isolation), thus suggesting that technology may trigger both positive and negative feelings. Similarly, the author in Ref. [24] argued that "the relative dominance of positive and negative feelings about technology would vary across people and cause corresponding variations in people's propensity to embrace and employ new technologies."

The TRI draws on qualitative research about people's interactions with technology to provide the means to measure how likely they are to adopt new technologies to improve wellbeing. Four dimensions were proposed in the TRI: two that positively motivate adoption (optimism and innovativeness) and two that negatively inhibit it (insecurity and discomfort). While the TRI focuses on people's subjective experience with technology based on their beliefs towards it, the technology acceptance model (TAM) considers how external factors influence intentions and beliefs. TAM was designed by observing perceived usefulness (i.e., how much a person believes that using a technology will improve their quality of life or work) and perceived ease of use (i.e., a person's perception of the amount of effort required in using the said technology). This model aims at understanding attitude towards the use of the technology, intention to use the technology, and actual use that occurs [47]. The TAM was subsequently improved, leading to a TAM 2.0

Table 6b
Indirect effects.

H	Indirect effects					B*A(b)	Bootstrapping Percentile 95% CI		p	Mediation Result
							Lower	Upper		
H3a	Empowerment	→	Citizen satisfaction	→	Continuous usage	.043	.007	.099	.041	Supported
H3b	Innovativeness	→	Citizen satisfaction	→	Continuous usage	.039	.012	.081	.019	Supported
H3c	Optimism	→	Citizen satisfaction	→	Continuous usage	.130	.059	.248	***	Supported
H4a	Empowerment	→	Discomfort	→	Continuous usage	.063	−.007	.162	.072	Not Supported
H4b	Innovativeness	→	Discomfort	→	Continuous usage	.001	−.021	.030	.892	Not Supported
H4c	Optimism	→	Discomfort	→	Continuous usage	−.027	−.109	.004	.186	Not Supported
H5	Inhibitors	→	Citizen satisfaction	→	Continuous usage	−.009	−.039	.010	.490	Not Supported
H6	Inhibitors	→	Discomfort	→	Continuous usage	−.199	−.402	−.033	.047	Supported

***p < 0.001; significant at .05 level; n = 350; H = hypothesis; b = unstandardized; CI = confidence intervals.

[151] and a later TAM 3.0 [152], which takes into account other aspects of technology use, such as those related to social influence and cognitive instrumental processes. Previous models of TAM were originally developed to predict technology adoption in authorized situations, however [153] argue its limitation when applied to users who are free to choose between several alternatives and emphasize that a model that considers individual differences is the TRI. Hence, our belief that TRI is the ideal model to build upon. In this work, we extended the TRI scale to model citizens' readiness for the continuous usage of SCS. A summary of our contributions and a discussion of the theoretical and practical implications of this work are discussed in the next two sub-sections, followed by a highlight of limitations and future work.

5.1. Summary of contributions

In this study, we reviewed relevant literature to determine which readiness factors can influence citizen post-adoption behavior and user retention of smart city services. Using data collected from 8 smart city experts and 350 citizens residing in the UAE, a model and hypotheses were developed and tested. Adding to the literature and knowledge body on smart cities and focusing on their social dimension [154,155], our study has two main contributions. The first contribution is the development of an extended TRI scale for measuring citizens' readiness to continue to use SCS, post adoption. As a second contribution, the research theorized the key readiness factors that affect the intention of SCS continuous usage, partially mediated by satisfaction and discomfort.

Table 7 gives the overview of how the TRI2.0 was extended to a SCS readiness scale. In our proposed scale, the first TRI 2.0 dimension related to optimism was kept and as operationalized as efficiency and personalization, in order to capture some of the unique characteristics of SCS that are typically data centric and rely on advanced features such as data analytics and machine learning. As shown in the table, four new items were proposed to capture this operationalizing of optimism. The first item (OPT1) is related the anticipation of future needs based on historical interactions – a prominent feature of SCS with smart recommendation engines. The second item (OPT2) is related to automatic decision making – a feature pertaining to artificial intelligence and machine learning capabilities envisioned for future SCS. The third item (OPT3) is related to an omni-channel capability enabling the integration and inter-connectedness of multiple systems to offer a seamless experience to users. The fourth element (OPT4) is related to ease and convenience of communication with service providers through different channels. It should be noted that the fourth original TRI2.0 items were removed since they were generic and concerned with a better quality of life, but did not capture any specific features related to SCS.

The innovativeness and insecurity TRI dimensions were retained, and their original items kept. The wording of the items was slightly modified to capture the context of smart technology. It should be noted that the INN3 items related to being able to dal with new technology without help was removed during EFA due to low factor loading.

The discomfort dimension was highlighted by Parasuraman and Colby [24] as being multi-faceted and more complex to measure. To address this concern, we enhanced this dimension by adding six new items in addition to the existing four items related to discomfort. The newly added items address different aspects of discomfort with technology, such as being overwhelmed with rapid change (DIS5), difficulty of accessibility modes (DIS6), resistance to change/innovation (DIS7 & DIS8), cost barrier (DIS9), complexity and difficulty of use (DIS10).

In addition to the existing TRI2.0 dimensions, we added three new dimensions that emerged from our qualitative research phase and the literature review. The first new dimension is empowerment, which contains three new items related to user control over the services in terms of access and sharing of personal data and redirection to other systems (EMP2, EMP3, EMP4). The second and third new dimensions (Mistrust and legal considerations) are meant to refine and add more granularity to the inhibitors dimension. Mistrust introduced four new items related to privacy concerns, lack of transparency and security related fears (MIS1, MIS2, MIS3, and MIS4). Legal considerations, which was initially part of insecurity, was separated as an independent dimension based on EFA results. This dimension addresses the lack of appropriate regulatory frameworks that control emerging technologies and services adoption (LEG1), concerns about weak authentication and access control mechanisms (LEG2), and changes in terms and conditions without user consent (LEG3). All new constructs were tested for validity and reliability.

5.2. Theoretical and practical implications

In terms of theoretical contribution, this study deepens the understanding of the factors that affect citizens' intention to continuously use SCS – whereas the quantitative results suggest that different factors have different effects. Building on the current literature on smart cities, this study provides a better understanding of smart city services and their unique characteristics. Furthermore, it develops and validates a model that considers the social and cultural aspects of smart cities and provides insights on the role of citizens' satisfaction and their intention to use future smart services. It should be noted that this study focuses on individuals as citizens, rather than employees in organizations. Finally, this work contributes to the investigations on citizens' readiness and post adoption behavior towards smart services by proposing a new technology readiness scale tailored to the context of smart cities. The key theoretical findings of the study are summarized as follows:

The first hypothesis (H1) was accepted and the findings confirm that citizens' satisfaction positively impacts their intention of SCS′ continuous usage. Evidence for this result comes from service research. For example, Chen et al. [39] results confirmed that user satisfaction is relevant for the future intention to use those services. While, MacDonald & Smith [96] also found that buyers' satisfaction has a positive and direct effect on future intentions. That implies that users' intention of continued usage of services can be assessed by measuring users' satisfaction.

One of the key contributions of this work lies in the second hypothesis (H2), which introduces discomfort as a mediating variable instead of a TR independent variable. While existing studies have not found any significant impact of discomfort as an independent variable, on continued usage [115,131], we examined discomfort as an outcome of inhibitors that in turn negatively influences intention of SCS' continuous usage. The idea is that inhibitors trigger a certain level of discomfort that reduces the chance of continuous usage and adoption [156,157]. Our results and findings confirmed that discomfort negatively impacts the intention of continuous usage of SCS.

All the enablers addressed in H3a, H3b and H3c (i.e. empowerment, innovativeness, optimism operationalized as efficiency) have a positive impact, partially mediated by satisfaction, on the intention to continuously use SCS. More specifically, citizens' empowerment has the strongest direct effect on the intention of continuous usage of SCS, when compared to the innovativeness and optimism. This finding highlights the importance of empowerment as a new construct and implies users' belief in their right to choose and control future services [101]. Moreover, empowerment can strengthen group and individual contributions to planning and decision-making processes [158]. Mäkinen [159] defines digital empowerment as the government's usage of information technology to increase communities' control over their lives and enhance networking, communication, and cooperation opportunities. It should be noted that, while power over one's data is an important concern, users also value the ability to choose when and how services will be activated – especially services with impact over comfort and habits [160].

Interestingly, the three enablers (empowerment, innovativeness, and optimism) where found to have no indirect impact on continuous usage, when mediated by discomfort (H4a, H4b, and H4c). While we excepted that enablers would reduce the level of discomfort and in turn positively

Table 7
Extending the TRI 2.0 to a smart city services readiness scale.

Dimensions	TRI 2.0	Action	SCS readiness scale
Optimism	OPT1: New technologies contribute to a better quality of life	New Item	OPT1: Smart city services anticipate my future needs based on my previous interaction
	OPT2: Technology gives me more freedom of mobility	New Item	OPT2: Smart city services make automatic decisions based on my situation
	OPT3: Technology gives people more control over their daily lives	New Item	OPT3: Smart city services connect me to multiple systems in the city
	OPT4: Technology makes me more productive in my personal life	New Item	OPT4: I find it convenient to communicate with smart city service providers
Innovativeness	INN1: Other people come to me for advice on new technologies	Item Kept	INN1: Other people come to me for advice on new smart technologies
	INN2: In general, I am among the first in my circle of friends to acquire new technology when it appears	Item Kept	INN2: In general, I am among the first in my circle of friends to acquire new smart technology when it appears
	INN3: I can usually figure out new high-tech products and services without help from others	Item Removed – low factor loading	
	INN4: I keep up with the latest technological developments in my areas of interest	Item Kept	INN4: I keep up with the latest smart technology developments in my areas of interest
Insecurity	INS1: People are too dependent on technology to do things for them	Item Kept	INS1: People are dependent on smart city service providers to do things for them
	INS2: Too much technology distracts people to a point that is harmful	Item Kept	INS2: I do not feel confident doing business with a place that can only be reached online
	INS3: Technology lowers the quality of relationships by reducing personal interaction	Item Kept	INS3: Too many smart services distract people to the harmful point
	INS4: I do not feel confident doing business with a place that can only be reached online	Item Kept	INS4: Smart city services lower the quality of relationships by reducing personal interactions
Discomfort	DIS1: When I get technical support from a provider of a high-tech product or service, I sometimes feel as if I am being taken advantage of by someone who knows more than I do	Item Kept	DIS1: When I get technical support from a provider or a high-tech product or service, I sometimes feel as if I am being taken advantage of by someone who knows more than I do
	DIS2: Technical support lines are not helpful because they don't explain things in terms I understand DIS1	Item Kept	DIS2: Technical support lines are not helpful because they don't explain things in terms I understand
	DIS3: Sometimes, I think that technology systems are not designed for use by ordinary people DIS2	Item Kept	DIS3: Sometimes, I think that technology systems are not designed for use by ordinary people
	DIS4: There is no such thing as a manual for a high-tech product or service that's written in plain language	Item Kept	DIS4: There is no such thing as a manual for a high-tech product or service that's written in plain language
		New Item	DIS5: I find it difficult to keep up with the latest smart services.
		New Item	DIS6: Smart city services pose access challenges in using them (e.g. they are running on small screens and using touch keyboards, don't have access support for disabled people).
		New Item	DIS7: New smart city services are not compatible with consumers' existing practices and habits.
		New Item	DIS8: Due to the regular updates of smart systems, the user experience can change dramatically.
		New Item	DIS9: Smart city services are costly.
		New Item	DIS10: Smart city services have complex user interfaces.
Empowerment [New]		New Item	EMP2: I want to decide whether to provide my personal information to smart city service providers
		New Item	EMP3: I want to have control over how smart service providers use my personal information
		New Item	EMP4: I want smart city services to ask me before directing me to another system or website
Mistrust [New]		New Item	MIS1: My personal information might not be treated with confidentiality by smart service providers
		New Item	MIS2: Smart city services hide important information from users (e.g., not showing the seat number in cinema ticket booked online)
		New Item	MIS3: Terms and conditions associated with smart city services change frequently and are hard to track
		New Item	MIS4: Smart city services payment methods are not secure
Legal Considerations [New]		New Item	LEG1: The lack of a regulatory framework controlling smart city services may hinder their adoption.
		New Item	LEG2: Some smart city services have weak authentication features
		New Item	LEG 3: Smart services change their terms and conditions, without their users' consent

impact the intention of continuous usage, the results proved otherwise. Indeed, discomfort does not play a mediating role between the enablers and citizens' continuous usage of SCS. This result may be explained by the composition of our data sample which consists mainly of explorers and pioneers (forming 82% of the participants) – i.e. individuals who are unlikely to be affected by discomfort when using new SCS, due to their psychological profile and their innate acceptance of new technologies [160]. Furthermore, when taken individually, innovativeness was found to be insignificant and have no direct impact on discomfort, while empowerment had a negative impact on discomfort and optimism/efficiency had a positive impact. This demonstrates that empowerment and the ability to control future SCS can lead to a reduction in the discomfort experienced when using those services [104, 105].

In hypotheses H5 and H6, we introduced a new higher order construct called "Inhibitors" that encompasses the three TR inhibitor variables – mistrust, insecurity, and legal considerations. As presented in Ref. [24], the inhibitor dimensions where found to be weak from a psychometric point of view (specially AVE) due to the fact that they represent a multitude of intersecting aspects that are difficult to represent as a homogenous construct. By defining two new inhibitor dimensions (mistrust and legal considerations) we aimed at introducing more granularity to the scale and addressing aspects that pertain to the characteristics of smart services. Moreover, by introducing "inhibitors" as second order construct that combines the effects of different inhibitors, we were able to address the limitation discussed in Ref. [24] and obtain meaningful results.

The results have shown that there exists no significant indirect effect of the inhibitors on continued usage, when mediated by satisfaction (H5). Therefore, satisfaction does not play a mediating role between the inhibitors and the citizens' intention to continuously use SCS. Interestingly, the higher-order construct introduced to represent inhibitors had a direct positive effect on continued usage, which is the opposite of what was expected. This may be explained by the composition of our dataset which consisted mainly of innovators and early adopters that readily embrace innovations and are not fazed by any inhibitors due to their psychological profiles. Research attests that digital natives who are exposed to and already assimilated to various digital environments, do not feel any discomfort or insecurities but have high propensity to adopt new innovation [161]. Another possible explanation of this result may be due to the context of our study which took place in the UAE – a country that invests significantly in technological infrastructures and where residents trust government-owned identity management systems that provide secure, unique and tamper proof digital identities [162]. Such federated identity management system led to higher levels of trust and encouraged citizens' adoption of government smart services [163].

The result for H6 indicates that inhibitors (as a higher-order construct) has a significant direct and indirect effect on continuous usage, when mediated by discomfort. As expected, inhibitors such as mistrust, insecurity and ethical considerations can trigger discomfort, which in turn reduces the chance of adopting and continuously using SCS. The combination of the inhibitors into a higher order construct and the introduction of discomfort as mediator to continued usage allowed us to uncover this interesting relation between those parameters – a novel relationship that is not present in the literature. Moreover, the indirect path going from inhibitors to continued usage through discomfort shows higher correlation than the direct path, thus validating the use of discomfort as mediating variable.

In addition to theoretical implications, our research findings have practical implications for smart city service providers, who can rely on those findings to inform the design of future smart services. Indeed, by taking the factors that could affect citizens' satisfaction and their intention to use smart services into consideration in their service design, service providers can ensure the success and sustainability of their operations and a long-term return on their investments. Moreover, the smart services technology readiness scale proposed can be used with various categories of users, before the rollout of new services. This will enable the move towards a bottom-up approach for the development of future smart services and will help service providers better align their services to meet citizens' expectations and improve their quality of life.

In summary, our empirical findings suggest that satisfaction and discomfort act as mediators to continuous usage, with satisfaction showing a positive impact and discomfort showing a negative impact. Moreover, enabling factors related to technology readiness (such as empowerment, innovativeness, and optimism) have a positive influence on post-adoption behavior, when mediated by satisfaction, but show no significant influence when mediated by discomfort. Finally, discomfort fully mediates the relationship between inhibitors and continued usage – leading to a significant direct and indirect impact of inhibitors on post adoption behavior.

From a practical perspective, strategists and policy makers need to focus on satisfying the enablers' dimensions when developing strategies to offer new smart city services, while putting an emphasis on empowerment which was shown to have the strongest effect on continued usage. Moreover, special attention needs to be given to the level of citizen's satisfaction with the current smart services and the level of discomfort they experience when using them, in order to innovate and create the next generation of services that would be sustainable and successful. More specifically, different aspects of discomfort such as overwhelm with rapid change, resistance to innovation, costs barriers, complexity and difficulty of use need to be taken into consideration and mitigated in the design and deployment stages of SCS, by managers, policy makers, and regulators. Furthermore, user control over the services in terms of access and sharing of personal data and redirection to other systems needs to be ensured, and privacy and security concerns need to be addressed through robust privacy and security policies and controls. Finally, appropriate regulatory frameworks need to be proposed to regulate and control the deployment and operation of emerging technologies and services.

5.3. Limitations and future directions

Our study has some limitations. First, although smart cities are emerging across the globe in both developed and developing nations, our study focused on just one country. This provides an opportunity for future research to examine the issue in other countries as well as other industries, thereby providing a more concrete ground for generalization. Further research is also needed to offer smart cities' comparative analysis, which is also lacking in this study. Besides, smart cities in developed nations might differ from newly emerging countries because of different regulatory settings. Those differences need to be accounted for in the literature. Second, existing literature presents various theories/conceptualizations of TR and to fully-capture the antecedents of intention to continuously use SCSs, a future research model might include other variables, such as critics' perceptions and citizens' technological skills. Third, correlating citizens' values to their intention of continuous usage is another area that can be studied in more depth. Fourth, to provide a more comprehensive understanding of factors that influence intention to adopt SCSs, future studies could combine interpretations from both service providers and users in order to develop comparative models that evaluate differences and similarities of their perceptions. Finally, our results are based on a cross sectional study design, hence it is not possible to determine cause-effect links. Future research should utilize other research designs (e.g., experiments or longitudinal data) to examine causality.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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