Factors affecting sustainability of smart city services in China

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Factors affecting sustainability of smart city services in China: From the perspective of citizens' sense of gain

Guanying Huang [a], Dezhi Li [a,*], Lugang Yu [a], Dujian Yang [b], Yan Wang [a]

[a] Department of Construction and Real Estate, School of Civil Engineering, Southeast University, Nanjing, 211189, China
[b] Department of Built Environmental, Technische Universiteit Eindhoven, 5600 MB Eindhoven, the Netherlands

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ABSTRACT

The citizen-centric smart city has become an essential paradigm for dealing with the problems caused by rapid urbanization. The Chinese government proposed enhancing citizens' sense of gain to achieve the citizen-centric development goal. To develop a more realistic improving path for the sustainability of smart city services (SCS), it is necessary to clarify the factors that affect citizens' sense of gain of smart city services (CSGSCS). To achieve this objective, 9 hypotheses were developed based on the modified expectation confirmation theory. Hypothesis testing, mediating effect testing, and heterogeneity analysis was conducted based on data collected from Nanjing citizens. The results indicate that: 1) Expectation-Perception Performance, including Content of SCS, Channel of SCS, and Support of SCS, all have positive direct effects on CSGSCS; 2) Expectation Confirmation directly affects CSGSCS and mediates the positive effect of the Expectation-Perception Performance on CSGSCS; 3) Heterogeneity of age and usage frequency have significant effects on CSGSCS. Finally, three policy implications were proposed, including encouraging citizens to participate in SCS supply, bridging the digital divide created by SCS, and improving the policy and legal system on SCS. This research enriches the academic framework and provides guidance for sustainable supply of SCS in similar cities around the world.

1. Introduction

More than half of the world's population now lives in cities, and this proportion is growing (Staletić, Labus, Bogdanović, Despotović-Zrakić, & Radenković, 2020). The United Nations estimates that cities will account for 68 percent of the world's population by 2050 (Pirlone, Spadaro, & Candia, 2020). Rapid urbanization has caused environmental pollution, traffic congestion, resource shortage, and other urban problems (Feng, Xiu, Bai, Zhong, & Wei, 2020). The smart city is becoming an emerging urban paradigm that applies advanced information and communication technologies (ICT) to supplement conventional planning and market tools (Deakin, Reid, & Mora, 2020; Tanda & De Marco, 2018). The International Standards Organization (ISO) explains that smart city services (SCS) include climate change adaptation, e-government, transport, logistics, healthcare, energy and resources, environmental protection, public safety, and community and household (Lin, Zhao, Yu, & Wu, 2019). These services permeate every corner of the city. Singapore first proposed constructing a Smart Island in 1992, focusing on strengthening the information technology foundation (Ma, 2020). After IBM put forward the concept of "Smart Planet" in 2008, many countries have launched smart city construction plans, such as "I-Japan" in 2009, "Smart Nation 2025″ of Singapore in 2014, and "Smart Cities" strategy launched by India in 2015. As the largest developing country in the world, China put forward the concept of smart city in 2010 (Wang, Zhou, & Wang, 2020). It is estimated that China had more than 500 smart cities in 2018, more than the rest of the world combined, covering all types of SCS in the world (Yao, Huang, & Zhao, 2020).

Although the SCS are driven by advanced ICT, it has become a global consensus that providing SCS is to improve citizens' quality of life (Chen & Chan, 2022; Deakin et al., 2020). The SCS aims not only to improve citizens' economic efficiency but also to meet citizens' needs and desires for social services (Jin et al., 2021). Since citizens are users of SCS, it is vital that their needs are taken into account when planning and delivering SCS (Zhu & Alamsyah, 2022). More and more scholars are convinced that fulfilling citizens' needs is the cause and goal of smart city construction sustainably (Krivy, 2018; Marsal-Llacuna, 2016; Yigitcanlar et al., 2019). As defined by the European Commission, the smart city is the place "where traditional networks and services are made

* Corresponding author.
E-mail addresses: hgy@seu.edu.cn (G. Huang), njldz@seu.edu.cn (D. Li), ylg_0701@seu.edu.cn (L. Yu), D.Yang@tue.nl (D. Yang), 1747536001@qq.com (Y. Wang).

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more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business" (Kummitha, 2019). Citizens' satisfaction with SCS has been an important criterion to measure the sustainability of smart city construction (Han & Kim, 2021), which has become the main focus of research (Lebrument, Zumbo, & Rochette, 2021). Most scholars evaluate citizens' satisfaction through case studies (Capra, 2016; Macke, Casagrande, Sarate, & Silva, 2018) or questionnaire surveys (Calzada, 2018; Pihlajaniemi, Luusua, & Juntunen, 2018). The influence of several factors has been verified, including citizen participation (Xu & Zhu, 2020), ease-of-use of SCS (Belanche-Gracia, Casaló-Ariño, & Pérez-Rueda, 2015), and individual characteristics of citizens (Abu et al., 2020).

Similar to most countries in the world, the Chinese government has adopted citizen-centric guidelines for providing SCS (Zhu, Li, & Feng, 2019). There is an explicit definition of the citizen-centric in China, which was proposed by Chinese President Xi Jinping in 2015. It is called the sense of gain, which refers to the sense of satisfaction arising from material and spiritual benefits obtained. Different from the definition of satisfaction, the sense of gain focuses more on whether citizens have obtained benefits (Gu, Yang, & Wang, 2020). However, there are limited studies so far that systematically measure the sense of gain of smart cities service (CSGSCS) in China.This study will examine which factors impact CSGSCS and how these impacts differ among heterogeneous user groups to fulfill the research gap. The goal is to guide resource allocation in the smart city construction to improve sustainability of SCS supply in China and other similar economics.

The article is structured as follows. Section 2 puts forward the theoretical framework, identifies the influencing factors of CSGSCS, and develops hypotheses. Section 3 introduces the process of designing survey and collecting data. The testing results of hypotheses, mediating effect, and heterogeneity analysis are presented in Section 4. Section 5 proposes the discussions and implications. Finally, section 6 presents the contributions, limitations, and future work.

2. Theoretical framework and research hypothesis

2.1. Modified expectation confirmation theory

Expectation-Confirmation Theory (ECT) was proposed by Oliver (1980) to define and predict customer satisfaction. Bhattacherjee (2001) verified the feelings and cognitive beliefs of the users to continue using the information system, and constructed an Expectation Confirmation Model, which explains the relationship between Expectation, Perceived Performance, Expectation Confirmation, and Satisfaction. As the most commonly used model to analyze users' satisfaction with services (Ashfaq, Yun, Yu, & Loureiro, 2020), ECT is widely used to analyze users' satisfaction with online taxi-hailing (Jin & Chen, 2021), outbound medical tourism (Mahmud, Rahman, Lima, & Annie, 2020), e-government service (Alruwaie, Haddadeh, & Weerakkody, 2020), massive open online courses (Pozón, Higueras, Muñoz, & Liébana, 2021) and other services. It can be found that the formation mechanism of the sense of gain is consistent with the satisfaction in ECT, both of which take the confirmation of users' material or spiritual needs as the premise. Therefore, this research proposed a theoretical framework of sense of gain modified from ECT, as shown in Fig. 1(b). The difference between Expectation and Perceived Performance has an impact on Expectation Confirmation in Fig. 1 (a). According to Alruwaie, El-Haddadeh, and Weerakkody (2020) and Jin and Chen (2021), Expectation and Perceived Performance are integrated into the Expectation-Perception Performance, in which specific latent variables need to be identified according to the research object. Expectation-Perception Performance can influence the Sense of Gain directly or through Expectation Confirmation.

2.2. Hypotheses development

Although the influencing factors of CSGSCS have not been systematically sorted, the relevant content has been mentioned scattered in relevant studies. According to the relevant literature, as shown in Table 1, the influencing factors of CSGSCS, namely Expectation-Perception Performance in Fig. 1 (b), can be divided into three dimensions, which are Content of SCS, Channel of SCS, and Support of SCS.

Content of SCS in this study refers to the measures that apply information technology to serve the citizen and create social value (Abu Salim, El Barachi, Onyia, & Mathew, 2020). Lytras and Visvizi (2018) argued that the public generally expressed serious concerns about the effectiveness and fluency of Content of SCS. In the field of technology-based services, the service content could affect users' Expectation Confirmation of products, which has been proved by many studies (Brill, Munoz, & Miller, 2019; Eren, 2021). Chatterjee and Kar (2018) found that the effectiveness and customization of Content of SCS can help improve the citizens' satisfaction with SCS in India. Ashfaq et al. (2020) verified that the completeness and effectiveness of service contents affect users' attitude toward chatbots. When their expectations

Table 1
Types of influencing factors of CSGSCS in related literature.

Code	Content of SCS	Channel of SCS	Support of SCS	Source
1	✓	✓		Ashfaq et al. (2020)
2	✓	✓		Jumaan, Hashim, and Al-Ghazali (2020)
3	✓	✓		Jin and Chen (2021)
4		✓	✓	Mylrea (2017)
5		✓	✓	Cahn, Katz, and Ghermandi (2020)
6		✓	✓	White, Zink, Codecá, and Clarke (2021)
7	✓	✓	✓	Peng, Nunes, and Zheng (2017)
8	✓	✓	✓	Losavio, Chow, Koltay, and James (2018)
9	✓	✓	✓	Lin et al. (2019)

Note: √ denotes that the influencing factors in the literature involve this type.

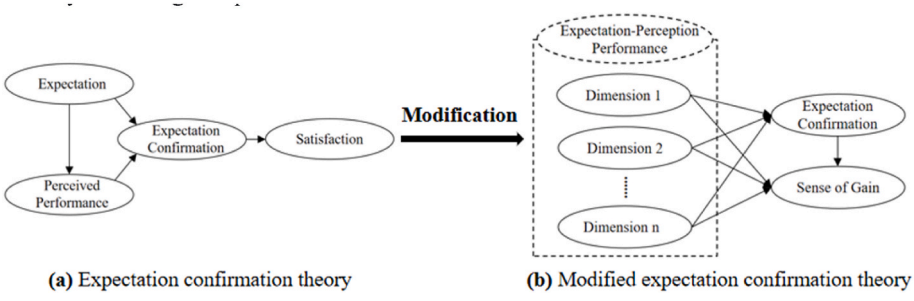

Fig. 1. Modification of theoretical framework.

were confirmed, citizens' subjective positive emotions also increase significantly (Dai, Teo, Rappa, & Huang, 2020; Kim, 2018). Therefore, hypothesis 1, hypothesis 2 and hypothesis 3 are proposed in combination with the conceptual research model in Fig. 1.

H1. Content of SCS is associated positively with Expectation Confirmation.

H2. Content of SCS is associated positively with CSGSCS.

H3. Expectation Confirmation is associated positively with CSGSCS.

Channel of SCS in this study refers to the means, modes or systems of SCS providers to provide SCS (Abu Salim et al., 2020; Kleijnen, de Ruyter, & Wetzels, 2007). Belanche-Gracia et al. (2015) proposed that the ease-of-use and security of channel are important factors affecting the public privacy perception on multi-service smart cards. Vaidya and Mouftah (2021) verified that the security and stability of the platform would affect the citizen's satisfaction with online car-hailing service. Some studies also found that uncertainty and complexity of channels could hinder citizens' perception on SCS (Buchanan, Banks, Preston, & Russo, 2016). Therefore, hypothesis 4 and hypothesis 5 are proposed.

H4. Channel of SCS is associated positively with Expectation Confirmation.

H5. Channel of SCS is associated positively with CSGSCS.

As for Support of SCS in this study, it is the technology, mechanism and policy to maintain the normal supply and acceptance of SCS. For example, Peng et al. (2017) analyzed online reviews of London's smart parking system and found that the technical and legal guarantees provided by local governments and service providers also influenced citizen's awareness in SCS. Lin et al. (2019) found that the breakdown maintenance and problem feedback mechanisms of China's smart infrastructure affected the perception of citizens. In addition, the sound legal system and other safeguards are the basis for the normal operation of Channel of SCS (Mylrea, 2017). And White et al. (2021) argued that support measures of SCS such as problem feedback and breakdown maintenance would also affect the supply of SCS. Therefore, hypothesis 6, hypothesis 7, hypothesis 8, and hypothesis 9 are proposed.

H6. Support of SCS is associated positively with Expectation Confirmation.

H7. Support of SCS is associated positively with CSGSCS.

H8. Support of SCS is associated positively with Content of SCS.

H9. Support of SCS is associated positively with Channel of SCS.

In addition to the Content of SCS, Channel of SCS, and Support of SCS, the demographics of citizens, including gender, age, income, and educational level, also have a significant impact on the CSGSCS. Several studies show that young citizens are more enthusiastic about using SCS and can better perceive the convenience brought by SCS (Brown & Venkatesh, 2005; Ha, Yoon, & Choi, 2007). Among the elderly, female groups are more cautious and have higher expectations than males before using SCS (Shin, 2015). Studies show that people with higher education and higher income are more sensitive to SCS (Ma, Chan, & Chen, 2016). In addition, the impact of citizens' usage frequency of SCS on citizens' perception has also been verified by some scholars (Venkatesh, Brown, Maruping, & Bala, 2008; Yeh, 2017). Therefore, the citizens' age, gender, income, education level, and usage frequency of SCS mentioned in the previous studies are selected as the control variables of the theoretical model in this research. Fig. 2 shows the theoretical model integrating all proposed hypotheses and control variables based on Fig. 1 (b).

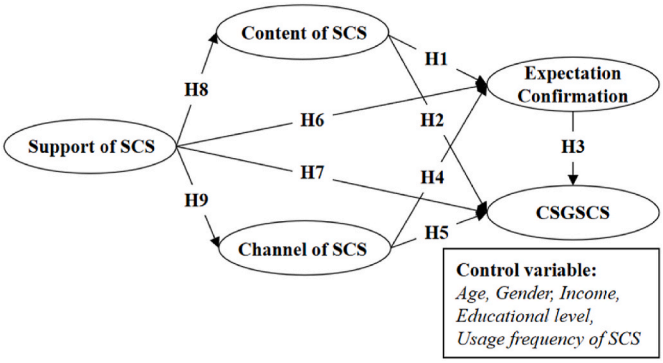

Fig. 2. Theoretical model.

3. Survey design and data collection

3.1. Survey design

To verify the theoretical model proposed in this study, the questionnaire includes three sections. The first section introduced the purpose of this survey and SCS frequently used by Nanjing citizens, such as smart transportation services (e.g. online car-hailing) and smart education services (e.g. MOOCs.). Although this study didn't divide SCS into specific categories, the introduction of these two examples can help respondents better understand the evaluation objects of the questionnaire. In the second section, individual socio-demographic information was asked, such as age, gender, income and educational level. The usage frequency of SCS was measured by a five point scale of "rarely (0 times per week)", "occasionally (1–3 times per week)", "sometimes (4–9 times per week)", "often (10–15 times per week)" and "usually (over 15 times per week)" according the researches of Ashfaq et al. (2020) and Yeh (2017). Questions used to measure the latent variables in the theoretical model were placed in the third section. Observed variables of Content of SCS, Channel of SCS, and Support of SCS were derived from literature, as shown in Table 2. The measuring questions of Expectation Confirmation were derived from the study of Bhattacherjee (2001). The measuring questions of CSGSCS were developed based on the definition of sense of gain provided by Gu et al. (2020) and Wan and Guo (2021). All observed variables were measured by a five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree").

To ensure comprehensiveness and validity of the questionnaire, the questionnaire was reviewed and revised by a panel of 23 experts, including SCS providers, smart device manufacturers, academic researchers, and government officials in the field of SCS. After that, the questionnaires were distributed to a focus group of 70 citizens for a pilot investigation. After several rounds of feedback and revision, the clarity of the questions was improved.

3.2. Data collection

The data collection was conducted in Nanjing, China. Nanjing is one of the first batch of smart city pilots in China with a mature SCS system. It is one of the ten megacities in China, with over 8.5 million citizens and the urbanization rate exceeding 80 percent in 2019. The data were collected from May 2021 to June 2021 using both online and paper questionnaire surveys to accommodate the disabled and elderly citizens who cannot easily fill in online questionnaires. To ensure the comprehensiveness of the sample, we randomly selected respondents from different types of communities in Nanjing and contacted them through the community residential committee. Respondents were asked to fill in questionnaires based on their experience on SCS in Nanjing. For the disabled and the elderly who were not able to complete the questionnaire online or by themselves, we interviewed them onsite and completed the questionnaire together with them. In order to achieve a

Table 2
Latent variables and observed variables in the theoretical model.

Latent variable	Observed variable	Source
Content of SCS	**Content of SCS1**: Do you agree that the SCS you use are effective?	Lee and Shin (2018); Mesa, Ortega, Pozo, and Piedra-de-la-Cuadra (2020)
	Content of SCS2: Do you agree that the SCS you use are fluent?	Lin et al. (2019); Ma (2020)
	Content of SCS3: Do you agree that the SCS you use are comfortable?	Auffenberg, Snow, Stein, and Rogers (2017); Stopps and Touchie (2020)
	Content of SCS4: Do you agree that the SCS you use are affordable?	Jin and Chen (2021); Saharan, Kumar, and Bawa (2020)
	Content of SCS5: Do you agree that SCS have personalized functions?	Chatterjee and Kar (2018); Yu, Ye, Lin, and Wu (2020)
Channel of SCS	**Channel of SCS1**: Do you agree that SCS are easy to use?	Abu et al., (2020); Belanche-Gracia et al. (2015)
	Channel of SCS2: Do you agree that SCS you use are security?	Chen, Wawrzynski, and Lv (2021); Vaidya and Mouftah (2021)
	Channel of SCS3: Do you agree that the appearance of SCS you use is aesthetic?	Jin and Chen (2021); Ma (2020)
	Channel of SCS4: Do you agree that SCS you use are compatible?	Lytras and Visvizi (2018); Yeh (2017)
	Channel of SCS5: Do you agree that SCS you use are stable?	Jin and Chen (2021); Peng et al. (2017)
Support of SCS	**Support of SCS1**: Do you agree that the problems you encountered with the SCS you used can be solved by feedback?	Lin et al. (2019); White et al. (2021)
	Support of SCS2: Do you agree that the SCS you use would be maintained in case of breakdown?	Lin et al. (2019); White et al. (2021)
	Support of SCS3: Do you agree that there is a sound legal and policy system to protect you when using SCS?	Mylrea (2017); Samouylov, Popov, and Semyachkov (2019)
Expectation Confirmation	**Expectation Confirmation1**: Your experience with using SCS was better than what expected.	Bhattacherjee (2001)
	Expectation Confirmation2: The service level provided by SCS was better than what your expected.	
	Expectation Confirmation3: Overall, most of your expectations from using SCS were confirmed.	
CSGSCS	**CSGSCS1**: You gain material benefit from SCS. (i.e. more income, better education, better medical care)	Gu et al. (2020); Wan and Guo (2021)
	CSGSCS2: You gain spiritual benefit from SCS. (i.e. more treated fairly, more aspirational, more respected)	
	CSGSCS3: What you have gained from SCS makes you more satisfied with the city.	

95% confidence level with a 5% confidence interval representing 8.5 million citizens, 385 complete responses need to be collected (Gu, Li, Zhu, & Wang, 2019). Finally, 925 questionnaires were completed, including 642 electronic questionnaires and 283 paper questionnaires. After screening of answering time and consistence, 89 invalid questionnaires were identified.836 valid questionnaires were finally used in this study with an effective rate of 90.38%. The demographic distribution of the sample is shown in Table A1 of Appendix A.

4. Results

The structural equation model (SEM) was applied to estimate the parameters in the theoretical model using AMOS23.0. The two-step approach recommended by Anderson and Gerbing (1988) was adopted in this study. The first step is to test the reliability and validity of the measurement model using confirmatory factor analysis (CFA). The second step is to test whether the hypotheses fit the theoretical model using the structural model. To estimate the influence of citizens' heterogeneity on CSGSCS, in addition, the independent-sample *t*-test and Analysis of Variance (ANOVA) were used with SPSS22.0.

4.1. Measured model

Reliability reflects the stability and consistency of the results obtained from the measurement model. As shown in Table 2, Cronbach's Alpha of each latent variable in this measured model range from 0.864 to 0.909, all of which meet the requirement of more than 0.7 (Zhou, Deng, Hwang, & Ji, 2020), indicating that the reliability of this measured model is acceptable.

Validity refers to the accuracy of the measured model to represent the research object, including convergent validity and discriminant validity (Cheng, Liu, Brown, & Searle, 2018). Convergent validity refers to the degree of correlation between the observed variable and the corresponding latent variable. As demonstrated in Table 3, the composite reliability (CR) of all latent variables in the measured model exceeds the recommended level of 0.7, and the average variance extracted (AVE) also satisfies the recommended level of 0.5. Furthermore, the normalized factor loadings (FL) of the observed variables range from 0.728 to 0.902, meeting the requirement of greater than 0.5 and significant at the level of 0.001. It indicates that the convergent validity of the measurement model meets the requirements (Li, Zhong, Jing, & Fan, 2019). Discriminant validity refers to the fact that the observed variables of different latent variables are not correlated. As presented in Table 4, all the correlation coefficients of latent variables range from 0.179 to 0.564, and the square root of AVE of each latent variable is greater than its correlation coefficients with other latent variables. It indicates that the discrimination validity of the measurement model meets the requirements (Fornell & Larcker, 1981).

4.2. Structural model

(1) Model fitness test

The structural model is used to estimate the relationships among the latent variables in the research framework. In order to ensure that the relationship can be accurately estimated, the fit indices of the integrated model need to be evaluated, including absolute fit, incremental fit, and parsimonious fit. As shown in Table 5, all the fit indices meet the recommended values, indicating that this hypothetical model fits the actual values.

(2) Hypotheses test

All hypotheses proposed in the theoretical model are supported significantly, as illustrated in Table 6 and Fig. 3. The results indicated that both Content of SCS and Channel of SCS positively affected Expectation Confirmation and CSGSCS. Expectation Confirmation also positively affected CSGSCS. Support of SCS positively affected Expectation Confirmation and CSGSCS and positively affected Content of SCS and Channel of SCS. The factor loadings between the latent variable and the observed variable represent the degree to which the observed variable can explain the latent variable. For the observed variable corresponding to Content of SCS, the explanation degree of Content of SCS3 is the highest while that of Content of SCS4 is the lowest. The standardized path coefficient between the latent variables represents the direct effect

Table 3
Reliability and validity test of measure model.

Latent variable	Item	FL	Mean	SD	Alpha	CR	AVE
Content of SCS	CO1	0.830	3.371	1.175	0.909	0.910	0.669
	CO2	0.843	3.418	1.203			
	CO3	0.853	3.317	1.216			
	CO4	0.828	3.499	1.174			
	CO5	0.728	2.854	1.023			
Channel of SCS	CH1	0.729	2.839	1.112	0.897	0.899	0.642
	CH2	0.883	3.444	1.181			
	CH3	0.853	3.437	1.166			
	CH4	0.777	2.896	0.938			
	CH5	0.754	3.523	1.076			
Support of SCS	SU1	0.828	3.408	1.076	0.868	0.870	0.691
	SU2	0.861	3.296	1.031			
	SU3	0.803	2.874	0.898			
Expectation Confirmation	EC1	0.902	3.463	1.043	0.875	0.875	0.701
	EC2	0.809	3.557	1.172			
	EC3	0.796	2.959	1.058			
CSGSCS	CSGSCS1	0.844	3.608	1.031	0.864	0.863	0.679
	CSGSCS2	0.753	2.965	1.108			
	CSGSCS3	0.870	3.480	1.102			

Note: SD denotes standard deviation; Alpha denotes Cronbach's Alpha.

Table 4
Correlations among latent variables.

Latent variable	Content of SCS	Channel of SCS	Support of SCS	Expectation Confirmation	CSGSCS
Content of SCS	**0.818**				
Channel of SCS	0.179	**0.801**			
Support of SCS	0.492	0.363	**0.831**		
Expectation Confirmation	0.385	0.482	0.492	**0.837**	
CSGSCS	0.470	0.458	0.485	0.564	**0.824**

Note: The diagonals are the square roots of the AVE.

Table 5
The recommended and actual value of fit indices.

Type	Index	Recommended value	Actual value
	Chi^2/df	<3	2.307
Absolute fit	GFI	>0.90	0.960
	AGFI	>0.90	0.947
	RMSEA	<0.08	0.040
Incremental fit	NFI	>0.90	0.968
	RFI	>0.90	0.961
	IFI	>0.90	0.981
	TLI	>0.90	0.978
	CFI	>0.90	0.981
Parsimonious fit	PGFI	>0.50	0.723
	PNFI	>0.50	0.809
	PCFI	>0.50	0.821

of those. The standardized path coefficient from Content of SCS to Expectation Confirmation is 0.188, which is significant at the level of 0.001. It represents that one unit change of Content of SCS will directly bring about 0.188 units change of Expectation Confirmation.

(3) Mediating effect test

Based on the test results of direct effect, it can be found that there may be a mediation effect in 9 paths of the theoretical framework. Bootstrap (5000) test was conducted for these paths. The results showed that the 95% bias-corrected confidence interval and 95% percentile confidence interval of the indirect effect in the 9 paths excluded zero, indicating that indirect effect existed in these paths, as shown in Table 7. Combined with the test results of direct effect, it can be judged that the mediating effects of these 9 paths are all partial mediating effects. The results showed that Content of SCS, Channel of SCS, and Support of SCS could positively affect CSGSCS through Expectation Confirmation, and Support of SCS could affect Expectation Confirmation and CSGSCS through Content of SCS or Channel of SCS, respectively. In addition, multiple chains mediating effects of Support of SCS affecting Expectation Confirmation through Content of SCS or Channel of SCS and then further affecting CSGSCS were also supported.

Table 6
Hypotheses test of the theoretical model.

Hypothesis	Path	Standardized path coefficient	SE	CR	*p* value
H1	Content of SCS→Expectation Confirmation	0.188	0.037	4.833	***
H2	Content of SCS→CSGSCS	0.250	0.031	7.351	***
H3	Expectation Confirmation→CSGSCS	0.294	0.036	6.472	***
H4	Channel of SCS→Expectation Confirmation	0.349	0.043	9.313	***
H5	Channel of SCS→CSGSCS	0.222	0.041	5.795	***
H6	Support of SCS→Expectation Confirmation	0.273	0.053	6.639	***
H7	Support of SCS→CSGSCS	0.136	0.049	3.315	***
H8	Support of SCS→Content of SCS	0.492	0.053	12.583	***
H9	Support of SCS→Channel of SCS	0.363	0.045	9.152	***

Note: $^*p < 0.001$.

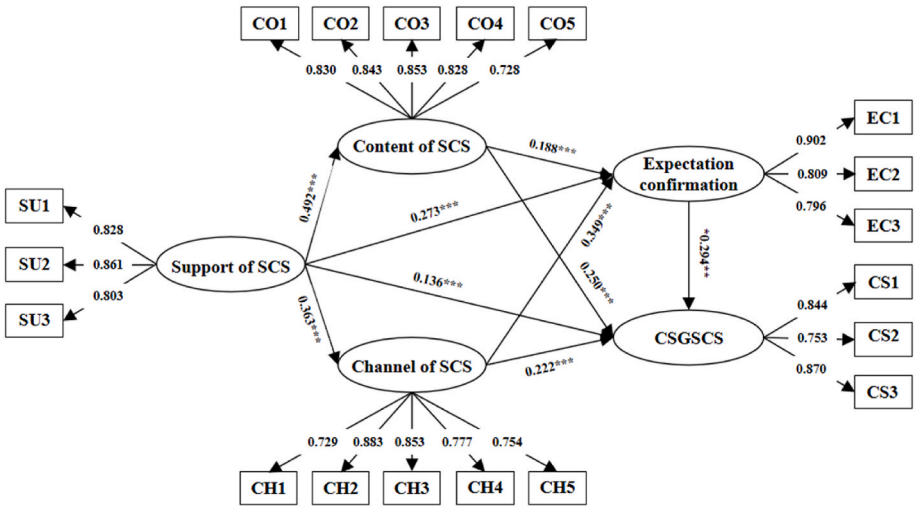

Fig. 3. Result of SEM analysis
Note: *$p < 0.001$. CO represents Content of SCS, CH represents Channel of SCS, SU represents Support of SCS, EC represents Expectation Confirmation and CS represents CSGSCS.

Table 7
Mediating effect of theoretical model.

Path	Indirect effect	SE	Bias-corrected 95% confidence interval			Percentile 95% confidence interval		
			Lower	Upper	P	Lower	Upper	P
Support of SCS→Content of SCS→Expectation Confirmation	0.093	0.022	0.054	0.139	0.000	0.052	0.136	0.000
Support of SCS→Content of SCS→CSGSCS	0.123	0.021	0.085	0.170	0.000	0.082	0.166	0.000
Support of SCS→Expectation Confirmation→CSGSCS	0.080	0.018	0.049	0.119	0.000	0.047	0.117	0.000
Content of SCS→Expectation Confirmation→CSGSCS	0.055	0.016	0.028	0.094	0.000	0.027	0.092	0.000
Channel of SCS→Expectation Confirmation→CSGSCS	0.103	0.020	0.067	0.147	0.000	0.066	0.145	0.000
Support of SCS→Channel of SCS→Expectation Confirmation	0.127	0.020	0.091	0.171	0.000	0.088	0.167	0.000
Support of SCS→Channel of SCS→CSGSCS	0.081	0.017	0.051	0.120	0.000	0.048	0.117	0.000
Support of SCS→Content of SCS→Expectation Confirmation→CSGSCS	0.027	0.008	0.014	0.048	0.000	0.013	0.046	0.000
Support of SCS→Channel of SCS→Expectation Confirmation→CSGSCS	0.037	0.009	0.023	0.059	0.000	0.022	0.056	0.000

4.3. Heterogeneity test of CSGSCS

To verify the heterogeneity of CSGSCS with different individual characteristics, independent-sample *t*-test was carried out on gender, and ANOVA test was carried out on other control variables such as age, educational level, income level, and usage frequency of SCS. As shown in Table A1 of Appendix A, the *p*-values of age and usage frequency of SCS were less than 0.05, which reached the significant level, while the *p*-values of gender, educational level, and income level were more than 0.05, which did not reach the significant level. Therefore, compared with the younger citizens, older citizens have a lower CSGSCS. This may be due to insufficient elderly-friendly SCS, which is consistent with the results of studies conducted in London (Choudrie, Obuekwe, & Zamani, 2021), Korea (Jun, 2020) and Latin America (Sunkel & Ullmann, 2019). The higher the usage frequency of SCS, the higher value of the CSGSCS. The reason for this difference may be that citizens' familiarity and dependence on SCS would increase with the increasing usage frequency of SCS, which has been confirmed by previous studies (Venkatesh et al., 2008; Yeh, 2017). However, gender, educational level, and income level had no significant difference in CSGSCS.

5. Discussions and implications

5.1. Discussions

The three main components of the hypothesis model, Expectation-Perception Performance, Expectation Confirmation and CSGSCS, are discussed respectively combined with the analysis results.

(1) Expectation-Perception Performance

Expectation-Perception Performance in the theoretical model of this study includes Content of SCS, Channel of SCS, and Support of SCS. All three have been verified to directly and indirectly positively affect CSGSCS. For Content of SCS, the factor loadings of Content of SCS1, Content of SCS2, Content of SCS3, and Content of SCS4 are all higher than 0.8, indicating effectiveness, fluency, comfortability, and affordability could well explain Content of SCS. On the other hand, the average score of Content of SCS5 is less than 3, showing that citizens are not satisfied with the customized personalized service on average. For Channel of SCS, the higher factor loadings of Channel of SCS2 and Channel of SCS3 reveal that the citizen is more concerned about the security and appearance of Channel of SCS. The lower average scores of Channel of SCS1 and Channel of SCS4 indicate that the ease-of-use and compatibility of the current SCS channel do not meet the citizens' expectations. The factor loadings of the three observed variables of Support of SCS are all greater than 0.8, proving that problem feedback, breakdown maintenance, and legal safeguard are all important for improving Support of SCS. However, the average score of Support of SCS3 is less than 3, indicating that citizens are not satisfied with legal and policy protection.

(2) Expectation Confirmation

Expectation Confirmation directly affects CSGSCS and mediates the positive effect of the three latent variables of Expectation-Perception Performance on CSGSCS, which plays a critical role in the theoretical model. The average scores of Expectation Confirmation1 and Expectation Confirmation2 are higher, indicating that the SCS currently provided exceeds the expectation of the citizens. While the average score of Expectation Confirmation3 is lower, showing that the current SCS could not satisfy the needs of citizens. The reason might be that the current SCS supply is in the top-down mode, and the suppliers fail to accurately capture the real needs of citizens and provide targeted services, which is similar to the research results of Gao, Wang, and Gu (2020) and Xu & Zhu (2020). The mismatch between supply and demand of SCS will cause unnecessary waste of resources and reduce the sustainability of smart cities.

(3) Total effects on CSGSCS

Among the observed variables of CSGSCS, the factor loadings of CSGSCS1 and CSGSCS3 are the highest, indicating that these two variables could significantly explain CSGSCS. It explains that the sense of gain of citizens who obtain material benefits from SCS is easier to be improved. On the other hand, the mean score of CSGSCS2 is less than 3, indicating that SCS supply did not bring enough spiritual benefits to citizens. The total effects on Content of SCS, Channel of SCS, Support of SCS, and Expectation Confirmation on CSGSCS were 0.305, 0.325, 0.485, and 0.294, respectively. Therefore, the change of Support of SCS had the greatest impact on CSGSCS. The strengthening of Support of SCS is a key measure to improve CSGSCS, which is consistent with other studies such as Kumar et al. (2021), Weber and Žarko (2019), and Axelsson and Granath (2018).

(4) Heterogeneity analysis of CSGSCS

SCS strives to make the lives of all citizens more efficient, but the heterogeneity of citizens poses great challenges to the SCS supply. Heterogeneity may create the digital divide, which blocks some vulnerable groups from the benefits of SCS. Similar to previous studies (Ma et al., 2016; Yeh, 2017), the age of citizens and the usage frequency of SCS are confirmed to affect CSGSCS significantly. It shows that the ease-of-use and elderly-friendly of SCS are not enough, and the digital divide needs to be further bridged. However, the influence of the income level of citizens on CSGSCS was not significant, which was different from studies of Elena-Bucea, Cruz-Jesus, Oliveira, and Coelho (2020) and Galperin and Arcidiacono (2021). The possible reason is that current SCS in China is mainly provided by the government for non-profit purposes. The price of SCS can be accepted by low-income citizens and avoid the digital divide between the rich and the poor.

5.2. Implications

Based on the analysis results, three policy implications related to citizen participation, digital divide, and policy and legal systems are proposed to improve the sustainability of SCS.

(1) Encouraging citizens to participate in SCS supply

The vital moderating effect of Expectation Confirmation on CSGSCS has been verified. To ensure that citizen's expectation is confirmed to a greater extent, citizens should be encouraged to participate in the whole process of SCS supply. During the planning period, the wide survey could be conducted for the citizens, to formulate the SCS supply plan oriented by the needs of citizens. In the period of smart facility construction, broadcast live can be used to make citizens supervise the construction of smart facilities. In the SCS operation process, the various channels should be provided to timely solve and feedback the problems citizens face. Besides, citizen satisfaction surveys could be conducted regularly to adjust the supply mode of SCS, ensuring the sustainability of SCS supply.

(2) Bridging the digital divide created by SCS

SCS supply is intended to improve the quality of life for all citizens in the smart city, but the accompanying digital divide becomes a hindrance to this goal. In order to reduce this obstacle, the government should strengthen the publicity of SCS so that more citizens can understand and accept SCS. Furthermore, the skill training should be widely conducted to improve the ability to use SCS by vulnerable groups such as the elderly and disabled citizens. The supplier should be encouraged to promote the ease-of-use and elderly-friendly of the SCS, protect the needs and interests of vulnerable groups, and enhance the inclusiveness of the SCS to bridge the digital divide. Enabling a wide range of citizens to benefit from smart city services is an important way to improve their sustainability.

(3) Improving the policy and legal system on SCS

As the latent variable with the greatest impact on CSGSCS, Support of SCS should be improved and strengthened continuously. Governments and associations in most cities in China have issued construction guidelines and management measures to guide SCS supply from a technical perspective. However, the policies and laws used to regulate the behavior of stakeholders in the SCS supply are still weak, leading to information security, privacy leakage, online rumors, and other problems. The disordered supply of SCS also reduces the resilience of smart cities. Therefore, the government should formulate a series of laws and policies, clarify the supervision department and regulatory authority in the SCS supply, and regulate the market order of SCS supply. Crack down on behaviors that infringe on the citizens' interests to reduce the security risk of SCS. Orderly and reliable supply of SCS in accordance with policies and legal systems will effectively enhance their sustainability.

6. Conclusions

Citizen-centric is the guide of the sustainable development of SCS, which has become the consensus of most countries globally. As the country with the largest number of smart cities under construction, China has a specific definition of this guideline to enhance citizens' sense of gain. This study firstly introduces the concept of sense of gain into the field of smart city, which is more consistent with the practical background in China. Specifically, Nanjing was taken as the study area to explore the influencing factors of CSGSCS. First, the theoretical model was established based on modified ECT, including Content of SCS, Channel of SCS, Support of SCS, Expectation Confirmation and CSGSCS. Then, the data were collected from Nanjing citizens by questionnaire survey. Next, the hypotheses were tested by SEM, and the heterogeneity of CSGSCS was verified by independent-sample t-test or ANOVA. The results indicated that Expectation-Perception Performance including Content of SCS, Channel of SCS, and Support of SCS all had positive direct effects on CSGSCS. Expectation Confirmation directly affects CSGSCS and mediates the positive effect of the Expectation-Perception Performance on CSGSCS. The heterogeneity of age and usage frequency had significant effects on CSGSCS. Finally, three policy implications were put forward, including encouraging citizens to participate in SCS supply, bridging the digital divide created by SCS, and improving the policy and legal system on SCS. Therefore, this research enriches the academic framework with more realistic research results and implications, which help other economies around the world understand the situation of SCS supply in China.

The findings of this study have to be seen in light of some limitations. First, this paper regards SCS as homogenous and did not consider the impact of different kinds of SCS on citizens' sense of gain. The

differences among services such as smart government and smart transportation should be explored in the future work. Second, this paper only sorted out the influencing factors of CSGSCS, and verified the influencing path. The simulation of the influencing path will be the focus of the following work to evaluate the effectiveness of various improvement measures.

Author statement

Guanying Huang: Data Curation, Visualization, Writing - Original Draft, Writing - Review & Editing. **Dezhi Li:** Conceptualization, Methodology, Supervision, Funding acquisition. **Lugang Yu:** Investigation, Data Curation, Visualization. **Dujuan Yang:** Writing - Review & Editing, Supervision. **Yan Wang:** Investigation, Data Curation, Formal analysis.

Declaration of competing interest

The authors do not have any conflicts of interest to declare.

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Appendix A

Table A1
Difference analysis of control variables

Item	Category	Amount	Mean	SD	F/T value	*p*-value
Gender	Male	404	3.384	0.943	0.957(T)	0.339
	Female	432	3.320	0.972		
Age	Under 18	109	3.480	1.030	5.860(F)	0.000
	18–30	392	3.460	0.858		
	31–40	213	3.272	0.996		
	41–50	83	3.012	0.962		
	Over 50	39	3.043	1.229		
Educational level	High school or less	172	3.382	0.965	1.550(F)	0.213
	College	537	3.312	0.953		
	Graduate school or higher	127	3.472	0.968		
Income level	Under 2500 CNY per month	166	3.450	0.914	1.019(F)	0.396
	2501-5000 CNY per month	345	3.327	0.966		
	5001-7500 CNY per month	180	3.265	0.945		
	7501-10000 CNY per month	95	3.375	1.035		
	Over 10,001 CNY per month	50	3.453	0.947		
Usage frequency of SCS	Rarely	175	3.257	0.857	4.856(F)	0.001
	Occasionally	245	3.260	0.876		
	Sometimes	211	3.330	0.985		
	Often	127	3.441	1.155		
	Usually	78	3.756	0.900		

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