An extended TOE framework for local government technology adoption for citizen participation: insights for city digital twins for collaborative planning

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Abstract

Purpose – This study aims to understand and explain factors that influence how, when and under which conditions local governments adopt digital technologies for citizen collaboration. It discusses what these findings mean for city digital twin adoption.

Design/methodology/approach – This research uses the systematic literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process to collect and evaluate evidence needed to answer the research questions. It uses the technology–organisation–environment (TOE) framework and proposes an additional dimension: "stakeholders" as the analytical framework.

Findings – Critical influential factors identified include the technology dimension: security and privacy; organisation dimension: top management support; environment dimension: political influence; and stakeholders' dimension: technological experience.

Research limitations/implications – This research extends the TOE framework and comprehensively analyses those factors which relate to citizens but significantly impact local government's decision to adopt digital tools for collaboration purposes. This research posits that in the context of local government technology adoption for collaboration, both the organisation and stakeholders' dimensions are critical.

Social implications – This research contributes to the government-citizen discourse and provides a constructive understanding of technological transformation in collaborative planning. The findings are helpful for local governments, researchers and geospatial industries as they offer a critical understanding of digital technology adoption, particularly city digital twins, for collaborative planning.

Originality/value – This study extends the TOE framework to include aspects relating to citizens. It provides a nuanced understanding of the influential factors and intricacies of technology adoption by local

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governments for citizen collaboration. It also discusses relevant issues of city digital twins' adoption by local governments for citizen participation.

Keywords Technology adoption, Local government, City digital twins, Collaborative planning, E-government, E-participation, Citizen participation

Paper type General review

Introduction

Collaborative planning is "an interactive process of consensus building and implementation using stakeholder and public involvement" (Margerum, 2002, p. 237). It is a two-way interactive planning and decision-making process between local government agencies and citizens (Godschalk and Mills, 1966). As noted by Patel *et al.* (2007), citizens possess valuable knowledge of their community and, therefore, can identify pertinent issues and perspectives of problems in their community. In land use planning and development processes, such collaboration is essential to facilitate the citizens' land use goals and needs (de Vries and Chigbu, 2017). It also ensures that citizens decide how their city or neighbourhood should look. Over the past decades, local governments worldwide have used various participatory methods such as public discussions, community meetings and surveys to solicit ideas and preferences from citizens on planning and development issues (Toukola and Ahola, 2022). With the increasing development and demand for digital services, local governments are leveraging the potential of digital technologies to collaborate with their citizens on planning interventions (Pettit *et al.*, 2006). In previous years, local governments have adopted several technologies for official use or to improve citizen participation in land use planning initiatives. Geospatial tools such as geographic information systems (GISs), multi-agency systems, gaming systems and CityGML aim to improve understanding of various land uses and scenarios (Biljecki and Ito, 2021). Digital participation tools such as Public Participation Geographic Information Systems (PPGIS) and social media platforms are also used to seek citizens' knowledge and proposals on planning issues in their community (Tulloch, 2008).

The advent of digital twins has spiked interest and discourse on how they can facilitate and improve collaborative decision-making between local government and citizens on planning interventions. According to Shahat *et al.* (2021), city digital twins offer the potential for citizens to understand their environments, create awareness of issues and have an opportunity to influence planning decisions. The city digital twins are digital data models of the city depicting the physical features within the city in different categories, layers and scales (Dembski *et al.*, 2020). By adopting it as a collaborative tool, citizens could assess the impacts of proposed land uses, identify existing land use issues and conflicts and influence urban land use decisions (Adade and de Vries, 2023).

Local governments' adoption of digital technologies, including digital twins, depends on several factors and issues relating to the technology itself, the organisation within these local governments, and external factors (Duhamel *et al.*, 2023; Rim, 2023). These factors either propel or hinder the adoption of technologies; therefore, despite the potential of digital technologies, local authorities must consider or meet certain criteria and be open to the adoption of such technologies. We position this research in a very specific way to analyse local governmental technology adoption for citizen collaboration and agenda-setting purposes. Therefore, we limit the study to technology adoption by local governments and emphasise those issues that determine technology adoption by local authorities for citizen collaboration.

To understand and explain factors that influence how, when and under which conditions local governments adopt digital technologies, we first evaluated various technology

adoption theories. Some of these theories include the technology acceptance model (Davis *et al.*, 1989), the technology–organisation–environment (TOE) framework (DePietro *et al.*, 1990), the diffusion of innovation (Rogers, 1983), the theory of planned behaviour (Ajzen, 1985), the structuration theory (Giddens, 1991), the unified theory of acceptance and use of technology (UTAUT) model (Venkatesh *et al.*, 2003) and adaptive structuration theory (DeSanctis and Poole, 1994). Among these, we used the TOE framework because it is an organisation-level theory (Baker, 2012) and provides a comprehensive, holistic and flexible framework to analyse organisational technology adoption behaviour (Nguyen *et al.*, 2022; Ullah *et al.*, 2021).

To unravel these issues, we undertake a systematic literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process to identify factors influencing local governments' adoption of digital technology for citizen collaboration. The study results are discussed in line with the dilemmas of city digital twin concepts and their adoption for citizen participation, collaboration and agenda-setting. The study aims to provide answers to the following research questions:

RQ1. Which dimensions of the TOE framework are crucial for local government technology adoption for citizen collaboration?

RQ2. What are the critical determinants of local government digital technology adoption for citizen participation, and what are the implications of these findings for city digital twins for collaborative planning?

The contributions of this study are as follows:

(1) This study extends the TOE framework to include aspects relating to stakeholders (e.g. citizens). The extension of the TOE framework complements and enhances the framework in the event of local government technology adoption for government–citizen collaborations. It expands the theoretical knowledge on organisational technology adoption and serves as a framework and research agenda for further discourse.

(2) It provides a nuanced understanding of the influential factors of local government digital technologies and e-participation adoption.

(3) The study also raises some critical factors relevant to local government's adoption of city digital twins for citizen participation in land use planning and agenda-setting processes.

The next sections of the paper are structured as follows: the second section presents the background of the study, describing city digital twins' concepts for collaborative planning, the technology–organisation–environment (TOE) framework and the rationale for its extension for this study. The third section introduces the methodology used for this study, while the next sections present the results and discussion, respectively. The sixth section is the final section, presenting the study's conclusions.

Background

City digital twins for collaborative planning

Digital twins (DTs) are digital representations of physical entities, people and processes (Grieves, 2019; Lehtola *et al.*, 2022). The digital twin concept was introduced by Micheal Grieves in 2002 for product lifecycle management (Grieves, 2019). Currently, it is applied in many areas, including the health sector (Elayan *et al.*, 2021),

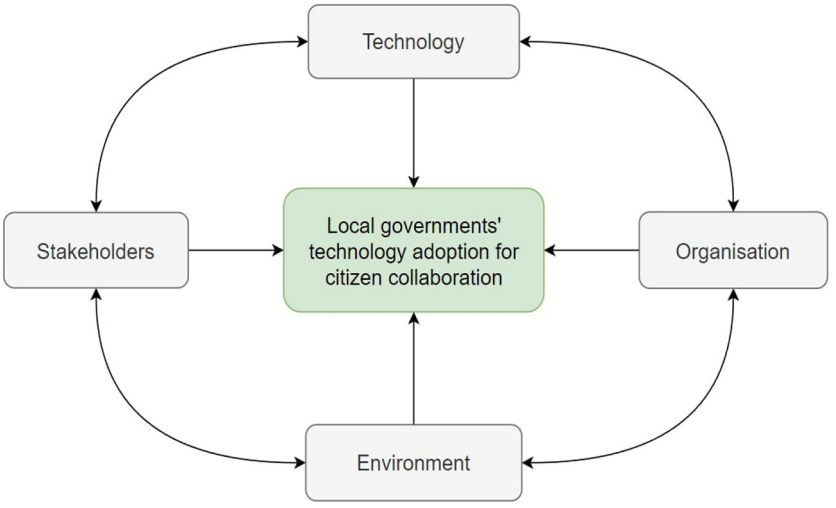
industry 4.0 (Catalano *et al.*, 2022), forest management (Buonocore *et al.*, 2022), construction management (Opoku *et al.*, 2021) and urban and rural planning (Shahat *et al.*, 2021). In the geospatial domain, DTs are used to model land parcels, buildings, proposed developments, a community, an area within a city or even an entire city or country (Adade and de Vries, 2023; Lehtola *et al.*, 2022). The digital twin concept implies that all physical assets are dual: their physical nature and their virtual version (Grieves, 2019). The physical assets and the virtual versions are connected using sensors to generate real-time data (Fuller *et al.*, 2020; Grieves, 2019). DTs are combined with advanced data analytics and facilitated through the Internet of Things for future predictions and data synchronisation across various agencies (Fuller *et al.*, 2020). The technology can simulate how interventions play out (Kušić *et al.*, 2023; de Vries, 2021). Analysis can also be performed on the virtual prototype without interfering with the physical assets (Vrabič *et al.*, 2018). Therefore, interventions are thoroughly and critically analysed before implementation. This helps avoid misguided decisions, time and cost. DTs are, therefore, decision support tools which offer realistic planning scenarios for users (Adade and de Vries, 2023). The idea of making such models accessible to citizens is to foster collaboration between local governments and citizens on land use planning scenarios and decision-making processes. Data generated from DTs are usually in 3D, offering better virtual visualisation opportunities to citizens. DTs also have interactive and dynamic analytical features used for complex analyses. These analytical features could help citizens select queries, data points and filters and visualise virtual models from different perspectives, angles or in an immersive environment (Botín-Sanabria *et al.*, 2022; Dembski *et al.*, 2020).

The technology–organisation–environment framework

The TOE framework is a theoretical framework developed by DePietro *et al.* (1990) to explain organisational logic and rationality related to the alignment of organisational (business) goal setting, strategic behaviour and promises of technologies. The TOE framework is one of the widely applied theories to understand technology adoption at the organisational level due to its comprehensive perspective and flexible adaptability in different fields of study (Nguyen *et al.*, 2022; Ullah *et al.*, 2021). It is therefore employed to understand factors influencing technology adoption by local governments as organisational actors with organisational behaviour rooted in certain professional epistemologies. The TOE framework emphasises that an organisation's decision to adopt a certain technology is based on the technological context, organisational context and environmental context (DePietro *et al.*, 1990). The technological context deals with the availability and characteristics of the technology. These include technologies available within the organisation and new technologies relevant to the organisation and can be adopted (Baker, 2012). The existing technologies determine the extent and speed of technological change, whilst the new technologies are expected to introduce incremental changes in features or versions compared to the existing technologies. The organisational context specifically looks at the organisation's size, structure, scope, human resources, technology adoption experience and financial strength to adopt certain technologies (Haneem *et al.*, 2019; Nguyen *et al.*, 2022). The environmental context deals with the particular setting within which the organisation operates and the policies surrounding the organisation's functions (Lippert and Govindarajulu, 2006). The TOE framework is, therefore, used to assess and understand technology adoption by local governments (Defitri *et al.*, 2020; Haneem *et al.*, 2019; Pudjianto *et al.*, 2011).

An extended technology–organisation–environment framework

The TOE framework was developed to assess an organisational decision to adopt technological innovations based on three dimensions – technology, organisation and environment. Despite the potential and comprehensiveness of the TOE framework, its primary constructs and constituents differ from one context to another (Bryan and Zuva, 2021; Shukla and Shankar, 2022). Therefore, in certain contexts, there is a need to extend it to holistically answer a research question. Falco and Kleinhans (2018) classify such factors as "contextual factors". For example, Bryan and Zuva (2021), in assessing the influential factors of building information modelling adoption, extended the TOE framework to include economic factors. The economic factors included are the return on investment and cost associated with training and consulting, which they deemed were not fitting in any of the dimensions of the traditional TOE framework. Also, to holistically assess the adoption of smart manufacturing, Shukla and Shankar (2022) included another dimension, "project management". Haneem *et al.* (2019) also extended the TOE framework to reflect an additional dimension, "individual characteristic", which they recognised as a significant issue in information technology adoption. As indicated in Figure 1, in the context of local governments' adoption of technology for citizen participation and collaboration in land use planning, issues, characteristics and factors relating to the stakeholders (e.g. citizens) are major relevant factors to consider. Previous studies on organisation-level or local government technological adoption include "individual characteristics" as a dimension to refer to personnel in the organisation (Haneem *et al.*, 2019; Wisdom *et al.*, 2014). In cases where citizen demand is included as a factor, it is normally under the environment dimension and is not comprehensively analysed. Indeed, factors that might influence the adoption of digital technologies by local government for internal use will not be the same when looking at local government digital technology adoption for citizen use or government-citizen collaboration. In the current study, we explore technology adoption by local governments for collaboration and citizen participation, not for internal or staff use.



Source: Authors' construct

Figure 1.
Four influential dimensions of local governments' technology adoption for citizen collaboration

Therefore, after a critical theoretical review and considering the objective of this study, four dimensions, namely, technology, organisation, environment and stakeholders (TOES), are most appropriate to assess technological innovation adoption comprehensively and holistically by local governments in the case of citizen collaboration and agenda-setting purposes.

Materials and methods

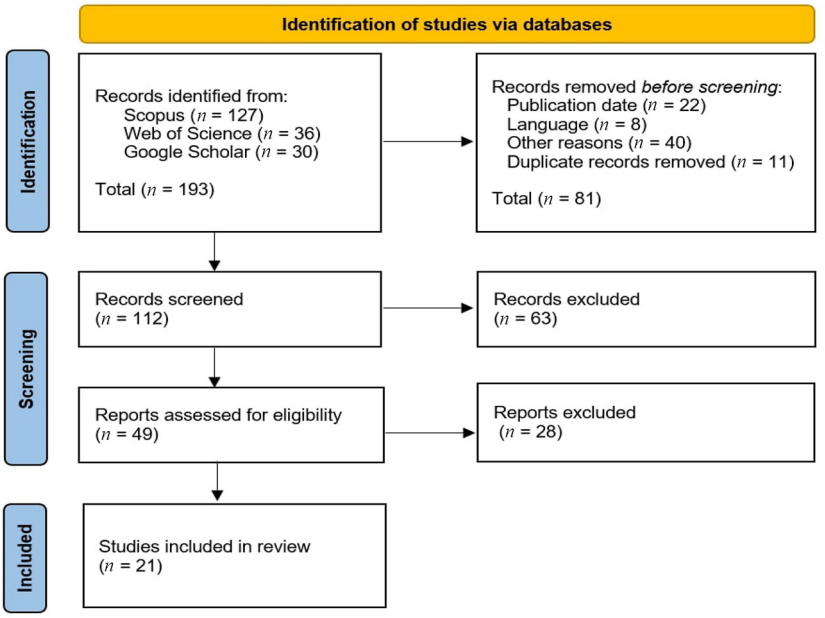
This study critically assesses influential factors of local government digital technology adoption for citizen collaboration using the technology, organisation, environment, and stakeholders (TOES) framework. The data collection and analysis are based on the systematic literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process. Precisely, this study followed the PRISMA 2020 checklist (Page *et al.*, 2021). The systematic literature review is adopted for this study because it is a rigorous method to evaluate, analyse and interpret previous studies on a particular subject matter or research question (Pollock and Berge, 2018). The study achieved this through the following steps: identification, screening process and inclusion.

Identification

The first step of the methodological process involved a literature search to identify relevant studies that align with and respond to the research objective. The search was performed on titles, abstracts, and keywords of articles on the following scientific databases: Web of Science, Scopus, and Google Scholar. To identify those studies that specifically address the research objectives, the search process was performed following the Boolean operation (("local government" OR "local authority" OR "municipality") AND ("digital technology" OR "digital tool" OR "digital twins" OR "e-democracy" OR "e-participation" OR "technology adoption") AND ("citizen collaboration" OR "citizen participation" OR "citizen engagement")). The search process was performed from September 2023 until April 2024 by the first author. Each database was last searched on 10 April 2024. The search was not limited to any geographic boundary. At the end of the search, we identified 127 articles from Scopus and 36 from Web of Science. The search process on Google Scholar resulted in many articles, so we selected "relevancy" and limited the selection to the first three pages (30 articles). The initial total number of records identified was 193. The selection was further limited to articles published from the year 2000 onwards to identify current issues, articles written in English (as it is the language the authors have a good command of), and peer-reviewed journal articles to ensure the rigorousness of the articles included. Therefore, articles published before the year 2000 were removed ($n = 22$), articles written in languages other than English were removed ($n = 8$), and other records were removed because they were either conference papers, books, book chapters, reports or editorials ($n = 40$). The remaining articles (see Supplementary material) were, therefore, extracted and imported into a systematic literature review software (Rayyan.ai). Following this, duplicates ($n = 11$) were removed. This brought the total number of articles for screening to 112.

Screening process

As shown in Figure 2, the evaluation stage started with a screening process. The articles were screened by title and abstract to select relevant papers for full-text reading. The aim of this study is to identify factors influencing local governments' adoption of digital technology for citizen collaboration. Therefore, the screening process was restricted to articles that address local government's digital technology adoption to ensure that articles included in the review identify issues relevant to assessing local government technology adoption and the purpose of improving citizen participation to identify relevant citizens'



Source: Page *et al*. (2021)

Figure 2.
PRISMA process

factors that would foster or impede the adoption of collaborative tools. We describe "local government context" to mean technology adoption by a municipality, local authority or city council and not, for example, a firm. The study (Alarabiat and Wahbeh, 2021) was not included in the review because it does not address technology adoption from the local government's perspective, while the study (Haneem *et al.*, 2019) was not included in the review, though it addresses technology adoption by local governments but not specifically for citizen collaboration. Articles with no full-text access were also removed. At the end of the title and abstract screening, 63 papers were removed, leaving 49 for full-text reading.

Inclusion

Studies which passed the screening phase were critically read. This involved analysing, interpreting and evaluating the contents of the studies. This step was the final selection stage. The selection process was done and agreed upon by all the authors. The quality assessment of articles in this stage was based on the inclusion and exclusion criteria in Table 1. For example, the study, (Maziashvili *et al.*, 2023) was not included in the review because it evaluates the post-adoption of technology. After the full-text reading, 28 studies were removed. Eventually, 21 studies were included in the review. Included papers address and identify influential factors of digital technology adoption by local governments for citizen collaboration and participation.

Results

The research analysed 21 articles to determine critical influential factors of digital technology adoption by local governments for citizen participation and collaboration using

Inclusion criteria	Exclusion criteria
Papers written in the English language	Papers not written in the English language
Papers published from 2000 to 2024	Papers publish before 2000
Peer-reviewed journal articles	Conference papers, books, book chapters, reports, editorials
Papers available online with full-text access	Papers with no full-text access
Papers that address influential factors of digital technology adoption by local governments	Papers that address technology adoption but not in the local governments' context
Papers that address influential factors of digital technology adoption by local governments for citizen collaboration	Papers that address technology adoption by local governments but not for collaborative purposes
Articles that evaluate the pre-adoption, pre-implementation, and testing phase or articles that assess factors that influenced the adoption if the technology is already adopted	Articles that evaluate post-adoption, post-adoption effects and post-implementation effects of technology

Source: Authors' construct

Table 1. Inclusion and exclusion criteria

the technology, organisation, environment and stakeholders (TOES) framework. The characteristics of the papers included in this review are presented in Table 2, while Table 3 summarises influential factors of local government's digital technology adoption for citizen collaboration, which are explained in the sub-sections.

Technology

The technological context refers to the characteristics, potential and issues relating to a technology. This includes the organisation's existing technologies and those that the organisation can adopt. According to Baker (2012), the existing technologies determine the extent and speed of technological change. In contrast, the new technologies are expected to introduce incremental shifts in features or versions compared to the existing technologies. Such changes should bring significant results in the planning activities of the local government. Critical influential factors identified under the technological context include perceived benefits, technology complexity and privacy and security. Perceived benefit is one factor that significantly influences local government adoption of digital technology (Adnan *et al.*, 2021; Jun and Weare, 2011; Zhang and Xiao, 2017). The assumption is that local authorities will likely adopt a technology that promises better government-citizen collaboration for responsible planning. Adnan *et al.* (2021) observed that most local government agencies across Indonesia adopted Web 2.0 because it initiates better communication and collaboration with citizens. The results also indicate that complexity is one of the most influential technology adoption factors. This is because the world is experiencing a high speed of technological change which local governments need to adapt and keep up the pace (Falco and Kleinhans, 2018; Hämäläinen, 2021). The use of participatory technologies also comes with security and privacy issues such as cyber-attacks and privacy exposure, which are critical concerns in most technological adoption processes (Babelon *et al.*, 2017; Gil-García and Pardo, 2005; Major *et al.*, 2021).

Organisation

The organisational dimension considers elements of the organisation that either support or impede the adoption of technologies. Critical influential factors identified

Table 2. Characteristics of papers included

Reference	Country	Local government	Research method	Type of paper	Technology/ innovation type	Citizen collaboration process
(Adnan *et al.*, 2021)	Indonesia	Multiple	Qualitative	Empirical	Web 2.0	To improve communication between government and citizens and receive feedback from the public on government initiatives
(Zheng and Schachter, 2018)	USA	New Jersey	Mixed	Empirical	E-participation	To enable citizens to give feedback on public issues and policies
(Tejedo-Romero *et al.*, 2022)	Portugal	Multiple	Quantitative	Empirical	E-government	Citizen participation and communication to ensure municipal transparency
(Dembski *et al.*, 2020)	Germany	Herrenberg	Mixed	Empirical	Digital twins	For citizens to identify and report urban challenges and influence urban planning decisions
(Savoldelli *et al.*, 2014)	General	General	Qualitative	Review	E-government	To seek knowledge from citizens on government initiatives
(Lidén, 2016)	Sweden	Multiple	Mixed	Empirical	Digital politics	Online engagement with citizens
(Sønderskov, 2020)	Norway	Multiple	Qualitative	Empirical	General	To involve citizens in policymaking
(Falco and Kleinhans, 2018)	General	General	Qualitative	Review	General	Government-citizen decision-making
(Zhang and Xiao, 2017)	China	General	Quantitative	Empirical	Social media	To increase government-citizen interaction
(Hämäläinen, 2021)	Finland	Helsinki	Qualitative	Empirical	Digital twins	To improve citizen involvement in smart city service provision
(Ahn, 2011)	USA	Multiple	Quantitative	Empirical	E-communication	To improve government-citizen communication
(Kamal *et al.*, 2013)	Pakistan	Multiple	Qualitative	Empirical	E-government	To improve communication between government and citizens, as well as service delivery
(Major *et al.*, 2021)	Norway	Alesund	Qualitative	Empirical	Digital twins	Citizen participation in smart city projects
(Ho and Ni, 2004)	USA	Iowa	Quantitative	Empirical	E-government	To improve communication between government and citizens, and public service delivery
(Sharif *et al.*, 2015)	Australia	Multiple	Qualitative	Empirical	Social media	To improve communication between local governments and citizens
(Babelon *et al.*, 2017)	Sweden	Multiple	Qualitative	Empirical	PPGIS	To involve citizens in urban planning decisions

(*continued*)

Table 2.

Reference	Country	Local government	Research method	Type of paper	Technology/ innovation type	Citizen collaboration process
(Manoharan and Ingrams, 2018)	General	General	Qualitative	Review	E-government	For citizens to provide feedback on public policies
(Mergel, 2018)	USA	General	Qualitative	Empirical	Challenge.gov	For citizens to share their ideas and suggestions with the government
(Jun and Weare, 2011)	USA	Multiple	Quantitative	Empirical	E-government	To improve communication between government and citizens and public service delivery
(Gil-García and Pardo, 2005)	Multiple	General	Qualitative	Review	E-government	For the promotion of democratic decision-making with citizens
(Jans *et al.*, 2016)	The Netherlands	Multiple	Quantitative	Empirical	E-government	For citizens to access public data and to ensure transparency

Notes: "Multiple" means the study was conducted in more than one municipality or country, while "General" refers to review articles and articles that describe technology adoption from the local government perspective but in a general sense
Source: Authors' construct

Table 3. Factors influencing digital technology adoption by local governments for citizen collaboration

Factors	Description	Reference(s)	Frequency
Technology			
Perceived benefits	This describes the advantages or potentials of technology to an organisation if adopted	(Adnan *et al.*, 2021; Hämäläinen, 2021; Jun and Weare, 2011; Sharif *et al.*, 2015; Zhang and Xiao, 2017)	5
Technological compatibility	This refers to the degree to which a technology or innovation is compatible with an organisation's existing technological systems	(Adnan *et al.*, 2021; Sharif *et al.*, 2015)	2
Cost of technology	This refers to the cost of acquiring, adopting, or implementing a technology	(Babelon *et al.*, 2017; Manoharan and Ingrams, 2018)	2
Technology complexity	This refers to the ease or difficulty of adopting, understanding and using technology	(Falco and Kleinhans, 2018; Hämäläinen, 2021; Major *et al.*, 2021)	3
Security and privacy	This refers to the risks associated with using technology. This could include cyber-attacks and privacy exposure	(Babelon *et al.*, 2017; Falco and Kleinhans, 2018; Gil-García and Pardo, 2005; Major *et al.*, 2021; Manoharan and Ingrams, 2018; Sharif *et al.*, 2015)	6
Technological resources	Technological resources refer to those resources needed to adopt or complement a technology. Examples include the internet, computer accessories and data storage systems	(Hämäläinen, 2021; Kamal *et al.*, 2013)	2
Organisation			
Technological competence	This describes the technological and IT skills and knowledge of personnel in the organisation	(Falco and Kleinhans, 2018; Gil-García and Pardo, 2005; Jans *et al.*, 2016; Jun and Weare, 2011; Lidén, 2016; Manoharan and Ingrams, 2018; Zhang and Xiao, 2017)	7
Innovation adoption culture	This refers to organisational behaviour to adopt a technology. Organisations with a track record of technological adoption will likely adopt new technologies	(Adnan *et al.*, 2021; Dembski *et al.*, 2020; Hämäläinen, 2021; Mergel, 2018; Tejedo-Romero *et al.*, 2022)	5
Financial resources	This refers to the financial strength and resources possessed by the organisation	(Babelon *et al.*, 2017; Jans *et al.*, 2016; Manoharan and Ingrams, 2018)	3
Top management support	This emphasises that technology adoption by a local government agency depends on the level of interest and support of top management, such as municipal or regional directors	(Adnan *et al.*, 2021; Ahn, 2011; Falco and Kleinhans, 2018; Kamal *et al.*, 2013; Lidén, 2016; Manoharan and Ingrams, 2018; Mergel, 2018; Sharif *et al.*, 2015; Sønderskov, 2020; Zhang and Xiao, 2017; Zheng and Schachter, 2018)	11
Open to citizen participation	The assumption is that a local government agency open to citizen participation is likelier to adopt technologies that foster citizen-government collaboration	(Adnan *et al.*, 2021; Babelon *et al.*, 2017; Falco and Kleinhans, 2018; Mergel, 2018; Zheng and Schachter, 2018)	4

(*continued*)

Table 3.

Factors	Description	Reference(s)	Frequency
Environment			
Policy and regulations	These refer to those policies or regulations that support or go against adopting certain technologies	(Adnan *et al.*, 2021; Falco and Kleinhans, 2018; Gil-García and Pardo, 2005; Hämäläinen, 2021; Lidén, 2016; Mergel, 2018)	6
Political influence	This is the degree of political support for the adoption of the technology	(Adnan *et al.*, 2021; Ahn, 2011; Gil-García and Pardo, 2005; Ho and Ni, 2004; Kamal *et al.*, 2013; Lidén, 2016; Manoharan and Ingrams, 2018; Mergel, 2018; Savoldelli *et al.*, 2014)	9
Governance structure	This refers to centralised and decentralised systems, power structure and the level of independence of the local government	(Adnan *et al.*, 2021; Babelon *et al.*, 2017; Mergel, 2018; Savoldelli *et al.*, 2014)	4
Interorganisational factors	These refer to the collaboration of other institutions which work jointly with local government agencies or the influence of other municipalities	(Jun and Weare, 2011; Mergel, 2018)	2
Stakeholders			
Citizen demand	This is the degree to which citizens require and influence the adoption of technologies. The assumption is that local governments will adopt a technology if it is a priority of the community	(Jun and Weare, 2011; Lidén, 2016; Sharif *et al.*, 2015; Zhang and Xiao, 2017)	4
Population size	Collaborative tools are likely to be adopted in municipalities with large populations	(Lidén, 2016; Tejedo-Romero *et al.*, 2022)	2
Community needs	The assumption is that local governments will adopt a particular technology if it responds to or solves a community need	(Dembski *et al.*, 2020; Mergel, 2018)	2
Technological resources	These refer to those resources available to citizens that will facilitate the adoption of technologies for collaborative purposes. These include internet access, computers and mobile phones	(Falco and Kleinhans, 2018; Kamal *et al.*, 2013)	2
Technological experience	Technological experience refers to the ability of citizens to understand and use digital technologies. This also refers to digital illiteracy and the digital divide	(Dembski *et al.*, 2020; Falco and Kleinhans, 2018; Jun and Weare, 2011; Kamal *et al.*, 2013; Manoharan and Ingrams, 2018)	5
Willingness to use	Adopting digital technology for collaborative purposes depends on whether citizens are willing to use the technology	(Dembski *et al.*, 2020; Kamal *et al.*, 2013; Mergel, 2018; Zhang and Xiao, 2017)	4

Source: Authors' construct

under the organisational context include technological competence, innovation adoption culture, top management support and openness to citizen participation. The study results indicate that in the organisational context, top management support is the most crucial determinant of technological adoption for citizen collaboration (Ahn, 2011; Lidén, 2016; Sønderskov, 2020; Zhang and Xiao, 2017). For example, Zhang and Xiao (2017) note that top management support is the strongest predictor of social media assimilation in government agencies because they provide essential internal political resources to overcome resistance. Also, organisations with a track record of technology adoption are likely to adopt new technologies (Mergel, 2018). Additionally, the results indicate that some administrative cultures generally adopt innovations that would improve citizen participation because they are open to such collaborative decision-making, while others are less open (Adnan *et al.*, 2021; Babelon *et al.*, 2017; Zheng and Schachter, 2018). Jans *et al.* (2016) found that previous e-government experience, technological skills and sufficient resources are the main factors influencing the early adoption of e-government innovations in Dutch municipalities.

Environment

The environmental context deals with the external factors that affect the functions and operations of the organisation (Lippert and Govindarajulu, 2006). The results show that policy and regulations (Jans *et al.*, 2016), political influence (Adnan *et al.*, 2021) and governance structure are critical elements under the environmental dimension. For example, government policies surrounding local government expenditure can limit its ability to adopt new technology (Adnan *et al.*, 2021; Mergel, 2018). Adnan *et al.* (2021) indicate that local government agencies in Indonesia must report administrative and planned programmes (including technology adoption) to the legislative body. The legislative body supports and advises the local government on budget allocation and the potential risks of adopting certain technologies. Again, technology adoption is influenced by governance structure, politics, political promises and, in most instances, the mayor's or top management's political affiliation and interest (Ho and Ni, 2004; Kamal *et al.*, 2013; Savoldelli *et al.*, 2014). Also, inter-organisational barriers and bureaucracy exist when two or more agencies collaborate in technological transformations (Mergel, 2018).

Stakeholders

The results have also demonstrated that influential technology adoption factors for collaborative purposes depend on those elements of citizens themselves. The results indicate that citizen demand (Sharif *et al.*, 2015), technological experience (Falco and Kleinhans, 2018; Kamal *et al.*, 2013) and willingness to use (Zhang and Xiao, 2017) are some of the critical influential factors relating to citizens. Citizen demand is an essential factor motivating local government agencies to adopt a technology. For example, Adnan *et al.* (2021) indicate that citizens' demand for public service quality and interaction with government agencies motivated the adoption of social media in many local government agencies in Indonesia. Falco and Kleinhans (2018) note that internet (in)accessibility, digital illiteracy and the digital divide in many societies are significant concerns for citizen-government digital engagements. Zhang and Xiao (2017) also show that citizen willingness and readiness significantly positively affect social media assimilation in government agencies in China.

Discussion

Critical dimensions of the TOE framework for local government technology adoption for citizen collaboration

The study uses the TOE framework and proposes an additional dimension: "stakeholders", to identify and explain critical influential factors of local government technology adoption for citizen collaboration. The study also sought to determine critical dimensions within the extended TOE framework for local government technology adoption for citizen collaboration. Contrary to our initial thought that factors relating to the technology dimension might have the most influence, all four dimensions positively influence local government technology adoption for collaborative purposes. Notwithstanding, in our opinion, both the organisation and the stakeholders' dimension have substantial effects on local government technology adoption for citizen collaboration.

Determining factors of local government digital technology adoption for citizen collaboration

The most critical factors (based on the number of articles indicating each factor) identified under each dimension, include the technology dimension: security and privacy; organisation dimension: top management support; environment dimension: political influence; and stakeholders' dimension: technological experience. Among all the factors identified, most of the papers reviewed indicate that top management support (under the organisation dimension) is the most crucial factor influencing local government technology adoption for citizen participation. For example, Zheng and Schachter (2018) note that there is a greater likelihood of extensive adoption of e-participation in municipalities where the senior administrator or municipal director has a stronger willingness to involve citizens. In other cases, the mayors are only interested in innovations that align with the promises and policies of their political affiliations (Adnan *et al.*, 2021; Kamal *et al.*, 2013). This is because, in most jurisdictions, the mayor and top local government directors are appointed by the ruling political party and, therefore, need to support the ideas and mandates of their political affiliations (Adnan *et al.*, 2021; Ahn, 2011). Unsurprisingly, the second most observed factor is political influence, which is primarily associated with top management support. Under the organisational dimension, factors such as technological competence, innovation adoption culture and openness to citizen participation were also identified and are critical for local government digital technology adoption for citizen collaboration. As noted by Mergel (2018), local governments will adopt new technologies for citizen collaboration if they have previously adopted collaborative tools and are open to involving citizens in decision-making.

The stakeholders' dimension indicates five essential factors for local government digital technology adoption for citizen collaboration; however, three were frequently observed: citizen demand, technological experience and willingness to use. In the era of technology and the internet boom, there is an increasing demand for government-citizen collaboration and efficient service delivery through digital means. For example, Adnan *et al.* (2021) note that some Indonesian municipalities adopted social media because the citizens demanded better communication and to ensure collaborative decision-making. Another critical factor under the stakeholders' dimension is the technological experience of citizens. That is, the ability of citizens to understand and use digital technologies is a prerequisite for local government's adoption of collaborative tools. Such issues are critical, especially when adopting technologies unfamiliar to many people and requiring high technology know-how. Unfortunately, there are issues of digital illiteracy and the digital divide in many societies (Falco and Kleinhans, 2018; Kamal *et al.*, 2013). Collaborative decision-making depends on the willingness of citizens to participate and take roles. Dembski *et al.* (2020) observed that

local governments will adopt collaborative technologies when there is a clear indication that citizens are willing to use the technologies and participate in social interventions.

Among all the factors identified under the technology dimension, most articles indicated that security and privacy are the major concerns when local governments are adopting government-citizen collaborative technologies. This is because there are tendencies of data leakage, misuse and commercial exploitation of information when sharing sensitive information across many platforms, agencies and stakeholders (Falco and Kleinhans, 2018). Therefore, local governments are more likely to adopt technologies that are more secure and leave no room for privacy breaches and vice versa (Sharif *et al.*, 2015).

Implication for city digital twins' adoption for collaborative planning

This research posits that both the organisation and the stakeholders' dimension have substantial effects on local government technology adoption for citizen collaboration and, for that matter, city digital twins' adoption. Therefore, factors such as top management support, technological competence of local government personnel, innovation adoption culture, openness to citizen participation, citizen demand, the technological experience of citizens and the willingness of citizens to use digital technologies are crucial for city digital twin adoption for collaborative planning. The implication of the results demonstrates that regardless of the anticipated benefits of an innovation or whether it satisfies all the other requirements, it is less likely to be adopted without the support and interest of mayors or municipal directors. This is also true for the city digital twins. For example, city digital twins are anticipated as facilitators for government–citizen collaboration due to their interactive and dynamic analytical features, cognitive reflections of the city and realistic planning scenarios, which provide better virtual visualisation opportunities and the development of scenarios (Hämäläinen, 2021; Major *et al.*, 2021). Despite the anticipated potential of city digital twins, their adoption heavily depends on the support and willingness of top local government authorities (Dembski *et al.*, 2020). Technology adoption for citizen collaboration depends on innovation adoption culture and how a particular local government is open to citizen participation and collaboration (Mergel, 2018; Tejedo-Romero *et al.*, 2022). Currently, the attention for and potential use of city digital twins are for more than just citizen collaboration; thus, such an idea only depends on a particular municipality. Therefore, administrative cultures with a track record of collaborative decision-making will likely adopt digital twins for citizen collaboration. Dembski *et al.* (2020), accordingly, suggest that policymakers must incorporate the idea of using city digital twins for citizen collaboration into their daily dialogue. Despite the spike in interest in digital twins, only a few cities have indicated their usage to improve government–citizen collaboration. The Singapore government is developing a virtual Singapore to synchronise all city data for various stakeholders, including citizens (Virtual Singapore, 2021). The authorities in Herrenberg are also developing digital twins for citizens to identify and report problems within the town and collaboratively decide on solutions (Dembski *et al.*, 2020). The authorities of Munich aim to work collaboratively with various stakeholders to improve climate protection and mobility services using digital twins (München Digital, 2022). The cities of Basel and Zürich also employ urban-scale digital twins to integrate city data for collaborative decision-making (Smart City Lab Basel, 2022; Stadt Zürich, 2022). City digital twins are more likely to be adopted by municipalities if their usage is not cumbersome and does not require high technological experiences. The demand for and willingness of citizens to use city digital twins for collaborative planning will also motivate local governments to adopt them.

Implication of "stakeholders" in the TOE framework for local governments' digital technology adoption for citizen collaboration

This research emphasises those factors that relate to citizens and affect the local government's adoption of technological innovations for citizen participation. The results have not only confirmed the importance of citizen demand for e-participation, e-government and technological innovations for government–citizen collaboration (Jun and Weare, 2011; Lidén, 2016), but have also drawn attention to factors such as population size (Tejedo-Romero *et al.*, 2022), community needs (Dembski *et al.*, 2020), technological experience (Manoharan and Ingrams, 2018), technological resources (Falco and Kleinhans, 2018) and the willingness of citizens to use such technologies to participate and take roles in planning activities (Zhang and Xiao, 2017). As indicated by Falco and Kleinhans (2018), there are still issues of internet accessibility, the availability of technological resources such as mobile phones or computers, digital illiteracy, and the digital divide in many societies. Also, knowledge and experience with the use of these tools is critical. Kamal *et al.* (2013), for example, reveal that limited access to computing resources, lack of education and citizens' economic conditions are critical factors inhibiting e-government adoption in Pakistan. The adoption of digital tools for government–citizen collaboration also depends on the population size (Lidén, 2016; Tejedo-Romero *et al.*, 2022). According to Tejedo-Romero *et al.* (2022), population size positively influences digital technology adoption because larger populations can form coalitions and demand digital services and transparency. The size of the population will also decide whether local governments will use digital forms of collaboration or traditional participation processes such as face-to-face community meetings. Zhang and Xiao (2017) also indicate that citizens' willingness and readiness to use government-citizen collaborative tools significantly affect local government's technology adoption. That is, local governments are motivated to adopt technological innovations (e.g. city digital twins) when citizens are willing or have the behavioural intention to use such systems. The inclusion of the stakeholders' dimension in the TOE framework has helped to identify factors such as community needs, population size, technological resources, technological experience and willingness to use. Also, the inclusion of stakeholders' dimension and, specifically, analysis of local government digital technology adoption for citizen collaboration has helped to identify and comprehensively analyse factors such as openness to citizen participation and innovation adoption culture, which are often overlooked. The factors identified are also essential to further the government–citizen e-collaboration discourse. This paper, therefore, contributes to the scientific literature on local government's adoption of technology for citizen collaboration.

Conclusion and future research

With the growing call for government-citizen collaboration in planning and increasing local government interest in city digital twins, this research identifies critical determinants of local government digital technology adoption for collaborative purposes. It analyses the implications of these findings for city digital twins' adoption for collaborative planning.

This research extends the TOE framework and comprehensively analyses those factors that significantly impact local government's decision to adopt digital tools for collaboration purposes. This research posits that the organisation and the stakeholders' dimension have substantial effects in the context of local government technology adoption for citizen collaboration. These are also prerequisites for successfully adopting and implementing city digital twins for collaborative planning.

Critical influential factors identified include the technology dimension: security and privacy; organisation dimension: top management support; environment dimension: political influence; and stakeholders' dimension: technological experience.

Regarding limitations, this research was particular and only included papers that address technology adoption by local governments and specifically for government-citizen collaboration. Also, based on the inclusion and exclusion criteria, we believe there could be other relevant articles that were not included in the study due to the predefined keywords, lack of full-text access and the inclusion of only papers written in English.

Future studies could empirically explore the significance of the stakeholders' dimension in the TOE framework. Additionally, further research should empirically assess local governments' (de)motivation for adopting city digital twins.

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Further reading

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Supplementary material

The supplementary material for this article can be found online.

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