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TraceTogether contact tracing: a Smart Nation innovation

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As urban populations grow, cities increasingly turn to smart city initiatives to enhance efficiency, citizen well-being, and economic development. Singapore's Smart Nation strategy exemplifies this trend by leveraging technology and citizen inclusion. This study investigates the key success factors of Singapore's smart city model, focusing on the TraceTogether app used during the COVID-19 pandemic. The research employs a mixed-methods approach, including a comprehensive literature review, conceptual framework development, and an in-depth case study of the TraceTogether application. Primary data was collected through semi-structured interviews with stakeholders such as policymakers, technology developers, and citizens and an analysis of digital platforms and feedback mechanisms. Findings show that Singapore's Smart Nation initiative succeeded due to strong governance, citizen trust, strategic technological implementation, and active public participation. The TraceTogether app showcased effective public health surveillance through a privacy-conscious, Bluetooth-based system. Citizen feedback was integrated via social media, interviews, and engagement programs like Smart Nation Ambassadors. The study underscores the importance of inclusive governance, cross-sector collaboration, and digital literacy in successfully implementing smart city technologies. While the TraceTogether app demonstrated efficient crisis response, challenges remain regarding data privacy, digital divide, and long-term scalability. The research offers insights for cities aiming to replicate Singapore's model by prioritizing citizen-centric design and adaptive policy frameworks.

KEYWORDS

smart technology, COVID-19, citizens participation, smart city, innovation, data analytics

1 Introduction

Cities face persistent challenges to enhance efficiency, improve citizens' wellbeing, and stimulate economic growth (Albino et al., 2015). As urban populations grow, cities are increasingly pressured to implement these strategies seamlessly, ensuring safety and providing essential public services. The United Nations predicts that by 2050, 68% of the global population will reside in cities, emphasising the urgency of addressing these challenges effectively (United Nations, 2018).

To navigate this growth, Ahvenniemi et al. (2017) propose indicators for sustainable and smart cities that help measure and monitor progress throughout the smart city journey. Grossi and Trunova (2021) reinforce this approach, highlighting the importance of measurable metrics in assessing the effectiveness of smart city initiatives. Despite these advancements, however, challenges remain, as the smart city concept is still evolving and needs full maturity (Grossi and Trunova, 2021).

Smart city projects are complex and more likely to fail than deliver the expected positive outcomes. They fail for various reasons, such as a limited understanding of the problems to be solved, a focus on technology solutions as proof of concept, and a tendency to follow the popular digitalisation trend in smart cities or public sector-targeted projects (Boorsma, 2018).

Incorporating technology solutions for citizen inclusion has gained significant importance, serving as a platform for citizens to actively engage in decision-making processes and contribute to the development of their communities (Geekiyange et al., 2021; Jiménez-Caldera et al., 2024). Through integrating technology in government operations and services, citizen-inclusive technology solutions have facilitated heightened efficiency, improved accessibility, and enhanced transparency. These solutions have recently witnessed widespread adoption, providing citizens with novel avenues for interaction and participation in governmental affairs (Alamoudi et al., 2022).

Cities strategically plan and implement smart city projects involving citizen participation and data analytics. In Norway, citizen involvement was integrated into the Design Sprint process, resulting in favourable project outcomes (Nielsen et al., 2019; Holum, 2023). Similarly, in Thailand, direct feedback from citizens was utilised to gather data for a proactive city maintenance strategy (Network Training Center (NTC), 2022).

Singapore's compact size, strong governance, and cohesive societal structure make it an ideal testing ground for smart city initiatives. As a city-state, its centralised governance enables rapid policy execution and seamless coordination among various governmental agencies. Unlike larger nations, Singapore's small geographic footprint allows for the efficient implementation of urban digitalisation projects without the logistical challenges associated with sprawling urban landscapes. Launched in 2014, the Smart Nation initiative exemplifies Singapore's long-term vision of leveraging technology to enhance urban living, public services, and economic opportunities (Sipahi and Saayi, 2024).

The government's proactive approach to policy-making and innovation is a key factor in Singapore's success with smart city transformation. The city-state allocates funding for technological advancements and promotes public sector innovation through dedicated agencies such as the Smart Nation and Digital Government Office (SNDGO). In contrast to other global smart city initiatives that rely heavily on private sector solutions, Singapore has prioritised insourcing technical competencies, ensuring that digital transformation aligns with national priorities (Woods et al., 2024).

Singaporeans' trust in government institutions further supports the city-state's digital transition. Having experienced rapid modernisation since independence in 1965, citizens have become accustomed to state-led development and innovation. Public support for digital governance initiatives, such as the National Digital Identity (NDI) and smart urban mobility solutions, has been mostly positive, contributing to the widespread adoption of smart technologies (Chang and Das, 2020).

This research explores how cities can incorporate citizen inclusion in their smart city projects and the impact of such inclusion on project outcomes. By examining these approaches, insights can be gained into effective strategies for achieving successful results in smart city initiatives. To illustrate this, the case study focuses on the TraceTogether app, launched in Singapore from 2020 to the end of April 2022 during the COVID-19 outbreak (Chew, 2022).

The rest of this paper is divided into four sections: Section 2, Conceptual Framework, and Section 3, Case Study. Section 4, Material and Methods, followed by Section 5, Results and Discussion, and Section 6, the Conclusion, consolidates and concludes the key findings of this research.

2 Conceptual framework

In Singapore, the Smart Nation initiative has benefited from the team's extensive experience with public sector processes, public policies, and citizen inclusion (Huang, 2001), contributing to the successful implementation of various smart city projects. Existing literature and reports provide insights into the factors that have led to the city-state's success.

The conceptual framework for the TraceTogether app case study (Figure 1) examines the factors contributing to the successful transformation of a traditional city into a smart city, or in Singapore's case, a Smart Nation, through citizen participation. This framework includes three key components: (1) the transition process from a current city to a smart city, (2) the role of governance in facilitating this transition, and (3) the mechanisms enabling citizen participation.

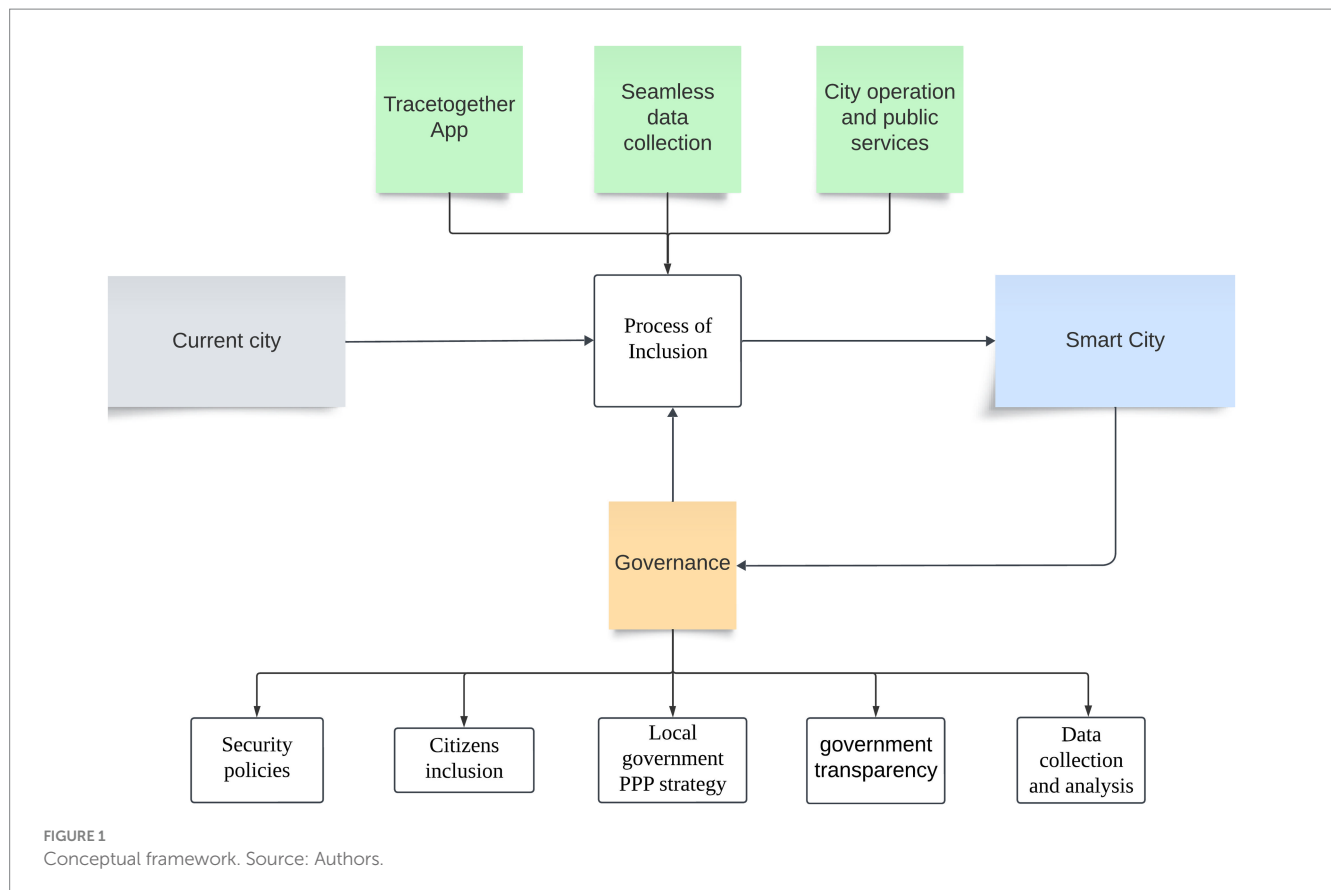
Transforming a city into a smart city involves a structured process of inclusion that integrates technological advancements and public services. The success of this transition relies on several key enablers: (i) Technological Innovations: Tools such as the TraceTogether app, seamless data collection, and improved city operations and public services enhance urban management and citizen engagement. (ii) Effective Data Utilisation: Smart cities depend on data collection and analysis to optimise services and ensure efficient governance. (iii) Governance and Policy Frameworks: Governance is crucial for establishing policies that promote transparency, security, and inclusivity in smart city initiatives (Sokolov et al., 2019).

Governance is fundamental in orchestrating the smart city transition by fostering an environment that encourages stakeholder collaboration. Key aspects of governance include: (i) Security Policies: Ensuring data privacy and cybersecurity to protect citizen data. (ii) Citizens' Inclusion: Actively engaging citizens in decision-making. (iii) Local Government PPP Strategy: Establishing public-private partnerships (PPPs) to drive smart city innovations and infrastructure development. (iv) Government Transparency: Maintaining openness and accountability in smart city operations and policies.

These governance factors collectively facilitate inclusion, which ensures the seamless integration of technologies and citizen participation into urban innovation strategies.

Rooted in e-governance and urban governance theories, this framework promotes the integration of digital technologies to enable cooperation among government agencies, private enterprises, and citizens (Nam and Pardo, 2011). This governance model aligns with Arnstein's citizen participation ladder, emphasising the significance of meaningful engagement rather than tokenistic involvement (Arnstein, 1969).

Key components of smart city governance include implementing strong security policies to ensure data privacy and cybersecurity, active citizen involvement in decision-making, strategic public-private partnerships, and maintaining government transparency (Reichental, 2020). Participatory planning is central to this governance model, as it encourages citizens to contribute to urban decision-making through



digital platforms, fostering co-creation and deliberative democracy (Simonofski et al., 2020).

The evolution of smart city governance has increasingly embraced participatory and data-driven models to enhance transparency, efficiency, and inclusivity (Meijer and Bolívar, 2016). Open government initiatives, such as crowdsourced policymaking and participatory budgeting, have proven effective in improving governance quality and public trust (Michels and de Graaf, 2017). However, implementing smart governance faces challenges, including gaps in digital literacy and the risk of exacerbating existing socio-economic inequalities (Cardullo and Kitchin, 2019). Balancing technological advancements with citizen privacy concerns requires continuous adaptation and innovative governance strategies.

A holistic approach to smart city governance integrates security, citizen participation, public-private collaboration, and transparency. By addressing these elements, cities can foster more inclusive, efficient, and responsive urban environments, leveraging technology to improve the quality of life for all residents. Ultimately, the success of smart city initiatives depends on the ability of governance structures to adapt to the rapidly changing technological landscape while focusing on citizen needs and societal wellbeing (Cardullo and Kitchin, 2019).

Citizen participation is a key driver of successful smart city initiatives. The value proposition of citizen engagement includes enhanced urban innovation, improved service delivery, and increased public trust in governance. Based on empirical data, the key mechanisms enabling citizen participation are: (i) Consultation: Citizens provide feedback on urban policies and smart city services through surveys and community discussions (Anthony, 2023). (ii) Collaboration: Co-creating solutions with stakeholders, including

government agencies, private sector players, and civic organisations (Leino and Puumala, 2021). (iii) Co-Creation: Direct involvement of citizens in the design and deployment of smart city solutions using digital platforms, such as social media, mobile applications, and participatory budgeting (Khan and Krishnan, 2021). Moreover, citizen inclusion ensures that smart city initiatives remain human-centred rather than purely technology-driven. Municipalities can enhance social cohesion, increase digital literacy, and promote trust between governments and residents by involving the public in policy discussions, decision-making, and service co-creation.

Digital platforms, such as mobile applications and open data portals, have become vital tools for fostering two-way communication between citizens and policymakers. These platforms enable real-time interaction, facilitate participatory decision-making, and enhance transparency in governance (Cortés-Cediel et al., 2021). However, digital inequalities persist, limiting participation among marginalised communities. Research shows that cities with strong digital inclusion strategies, like Singapore's Smart Nation initiative, tend to achieve higher levels of citizen engagement (Lim et al., 2018). Nevertheless, an over-reliance on technological solutions without addressing broader socio-political factors can lead to participation disparities, where certain groups remain excluded due to a lack of access to digital resources (Van Der Graaf and Ballon, 2019).

Recent research also suggests that human-centred design principles and co-creation methodologies are essential to fostering inclusive participation in technology-driven urban innovation (Simonofski et al., 2019).

The concept of "uneven innovation" further underscores disparities in smart city development, where technological advancements tend to

benefit certain socio-economic groups more than others (Costales, 2022). While digital transformation can drive efficiency and sustainability, it may also widen socioeconomic divides if equitable access to digital infrastructure and digital literacy programmes is not prioritised (Limna, 2023). In response, scholars advocate for participatory frameworks that integrate citizen voices at every stage of smart city development, ensuring that innovations are accessible and beneficial to diverse urban populations (Athanasios, 2023).

Smart cities increasingly adopt participatory approaches emphasising citizen-led initiatives to promote more inclusive urban innovation. For instance, the “Our MK” initiative in Milton Keynes, UK, supports citizens in developing and implementing data-driven solutions to local urban challenges (Wolff et al., 2018). Similarly, initiatives such as the CitiVoice Framework in Belgium categorise citizen participation into democratic involvement, co-creation, and ICT-user engagement, providing a structured methodology for enhancing participatory urban governance (Simonofski et al., 2019).

Approaches such as participatory urban laboratories and digital deliberation platforms have shown promise in strengthening local governance by incorporating citizen insights into smart city policy and infrastructure planning (Carvajal Bermúdez and König, 2021). A critical aspect of these approaches is the feedback processes that allow citizens to provide their opinions and insights directly to governance bodies. These feedback mechanisms help bridge the gap between government and community by fostering a collaborative environment where citizen voices are heard and actively shape decision-making. Research indicates that when citizens engage in feedback processes, governance becomes more transparent, trust in public institutions increases, and policies better reflect community needs and preferences (Tappert et al., 2024). Additionally, diverse citizen participation enhances the deliberative process, leading to innovative solutions for urban challenges and fostering a stronger sense of ownership among residents (Bremser et al., 2019). Moreover, studies highlight that digital platforms such as social media and e-participation tools significantly impact citizen engagement by creating accessible, decentralised spaces for deliberation and collective decision-making (Alarabiat, 2016).

3 Literature review and case study

Ahvenniemi et al.’s (2017) study compares smart city and urban sustainability assessment frameworks. A key finding is that smart city frameworks emphasise Information and Communication Technology (ICT) and social and economic aspects, while sustainability frameworks focus more on environmental concerns. The study highlights a fundamental discrepancy in how these two frameworks address urban development priorities.

One of the most surprising findings is the lack of environmental indicators in smart city frameworks despite substantial investments in energy, transport, and ICT research. In contrast, urban sustainability frameworks emphasise sectors such as the natural environment, built environment, water and waste management, and energy. Another major observation is that smart city indicators heavily focus on human and virtual environments rather than physical infrastructure, which could result in gaps in holistic urban sustainability.

Moreover, social sustainability aspects are addressed more thoroughly in smart city frameworks than in traditional sustainability

frameworks, which responds to previous criticisms of sustainability models for underemphasising social inclusion and citizen participation. Economic sustainability is also well covered in smart city assessments, challenging earlier perceptions that economic development could conflict with environmental sustainability (Ahvenniemi et al., 2017).

The study concludes that the term “smart sustainable cities” may be more appropriate than “smart cities” to ensure that sustainability considerations are not overlooked in urban development. Additionally, it recommends that future smart city assessment frameworks incorporate impact indicators that measure contributions towards environmental, economic, and social sustainability goals, rather than just tracking the efficiency of technology deployment (Ahvenniemi et al., 2017).

Grossi and Trunova’s (2021) research builds on the assessment frameworks by integrating the United Nations Sustainable Development Goals (SDGs) as a global measurement tool for smart and sustainable cities. Their analysis emphasises the role of Key Performance Indicators (KPIs) in capturing multiple values across economic, social, and environmental dimensions. Notably, the study critiques the one-size-fits-all approach of global KPIs, highlighting the need for localised adaptability to reflect urban complexities better.

A key contribution of their study is demonstrating how UN KPIs were applied in Moscow, revealing strengths in digitalisation but weaknesses in environmental performance. This highlights the importance of balancing ICT-driven smart city initiatives with sustainability efforts (Grossi and Trunova, 2021).

Table 1 summarises the key indicators and their respective metrics from Ahvenniemi et al. (2017) and Grossi and Trunova (2021).

Among the most impactful indicators, ICT-driven governance and digital infrastructure metrics have gained significant traction in modern smart city initiatives. Digitalisation efforts like those in Moscow are essential for streamlining city services and enhancing governance efficiency. However, as Grossi and Trunova (2021) note, these efforts often come at the cost of environmental sustainability, requiring balanced urban policies (Tables 2, 3).

Nature-based solutions (NBS), which include preserving green spaces and enhancing biodiversity, are increasingly being implemented to counteract urban heat islands and improve air quality. Cities such as Singapore and Copenhagen have incorporated urban forests and permeable infrastructure into their resilience strategies. Recent studies emphasise the role of NBS in enhancing urban sustainability. For instance, Aghaloo and Sharifi (2024) discuss the integration of NBS to create more resilient urban environments, while McPhearson et al. (2023) highlight the importance of biodiversity in urban planning (Aghaloo and Sharifi, 2024; McPhearson et al., 2023).

Singapore has been ranked among the top smart cities globally for its strong urban innovation initiatives (KPMG, 2021; Bris et al., 2021). The city-state has also demonstrated resilience in coping with sudden pressure and change during the COVID-19 pandemic from 2020 to 2022 (Ong, 2021). Ranking reports, such as those by Bris et al. (2021), suggest mobility, health, education, and governance indicators (Bris et al., 2021). Similarly, the UN’s Sustainable Development Goals (SDGs) may also contribute to these indicators as cities establish their strategies (Grossi and Trunova, 2021); SDG 11 covers city indicators, including affordable housing, mobility, infrastructure, green spaces, cultural heritage, and social support systems (Hui et al., 2023; United Nations, 2021). This leads cities today to develop more sustainable strategies in their vision, as there is a gap in the current smart city framework regarding sustainable development (Ahvenniemi et al., 2017).

Many cities need more time to prepare to invest in and develop smart city projects. As [Khan et al. \(2020\)](#) explain, multiple factors impact the success of such projects. These factors include a lack of resources, budgetary constraints, technology infrastructure and skills, social support, and an internal drive towards an overall vision.

The Singapore Smart Nation has a technology-focused strategy, as indicated by the numerous apps made available by the local government. These apps aim to provide citizens more efficient services and collect data for analysing and improving public services and processes. The list of apps available to citizens includes ActiveSG, CustomsSG, HealthHub, Healthy365, LifeSG, MyENV, MyResponder, MyTransportSG, NLP Mobile, OneMap, OneService, ParentGateway, Police@SG, Parking.sg, SGBioAtlas, SGSecure, SingPass, and SingStat ([Smart Nation, 2023](#)).

SingPass represents the most significant achievement of the Smart Nation project, enabling citizens to access government services through a single sign-on authentication while offering a wide array of services. Other applications like ActiveSG, CustomsSG, HealthHub, and LifeSG provide convenience and access to government services. NLP Mobile serves as Smart Nation’s library app, allowing citizens to access books and manage library inventories. MyENV, MyResponder, MyTransportSG, ParentGateway, and Police@SG offer additional convenience and security-related services (<https://www.smartnation.gov.sg/files/publications/smart-nation-strategy-nov2018.pdf>; [PMO, 2024f, 2024e](#)). Lastly, Parking.sg and SGBioAtlas deliver specialised

services to help find parking spots and learn about local wildlife. The “OneService” mobile app allows citizens to seek assistance in their vicinity, enabling them to provide feedback and reports on the public services they have used, which helps the government identify areas for improvement and continually enhance public service delivery. Furthermore, citizens can book facilities such as BBQ pits, workshops, sports, and more ([PMO, 2024d](#)).

In 2003, Singapore experienced an outbreak of SARS, with over 8,000 infections and around 774 deaths. In 2020, COVID-19 was identified as a similar virus, prompting concerns among Singapore officials about managing a potential outbreak. A multi-ministry task force was established within the government to coordinate efforts across various ministries as case numbers rose and strategies needed to be implemented swiftly. When the first lockdown was activated, the government recognised that it would impact citizens and businesses, necessitating a revised budget plan. This first lockdown, known as the circuit breaker, was projected to last 4 weeks ([Tan and The Straits Times Covid-19 Team, 2022](#), p.107).

On March 20, 2020, the TraceTogether app was launched as a government initiative to track COVID-19 and manage infection cases as efficiently as possible. Unlike in other countries, citizens embraced this app to facilitate their movement around the city. Additionally, it became mandatory by law to register entry locations with all businesses and malls. Before the TraceTogether app, manual registration of names, identification numbers, and contact numbers

TABLE 1 Key indicators and their respective metrics.

Indicator	Metrics	Description
Natural environment	Air/water quality, biodiversity, green spaces	Measures ecological health of urban areas
Built environment	Sustainable architecture, urban resilience	Ensures long-term viability of infrastructure
Water and waste management	Waste recycling rates, water efficiency	Focuses on sustainable waste treatment
Energy	Renewable energy use, energy efficiency	Tracks sustainability of energy systems
Economy	Employment rates, business growth	Evaluates local economic resilience
Education, culture, and innovation	Research investment, cultural engagement	Assesses societal innovation levels
Wellbeing, health, and safety	Healthcare access, public safety indices	Captures citizen wellbeing and security
Governance and citizen engagement	E-governance, policy participation	Measures effectiveness of civic involvement
Transport	Public transit efficiency, smart mobility adoption	Examines urban mobility solutions
SDG-aligned smart city assessment	UN KPIs integration, SDG target adherence	Evaluates city progress on global SDGs
Digitalization	ICT penetration, smart service usage	Measures effectiveness of digital city services
Cross-sector collaboration	Public-private partnership effectiveness	Tracks engagement of multiple urban stakeholders

Source: Authors.

TABLE 2 Smart city success factors.

Success factor	Description	Author(s)
Strategy	Clear vision and execution plan, including funding, progress metrics, and governance models.	Hämäläinen (2020)
Technology	Implementation of digital infrastructure, data analytics, and IoT to enhance urban management.	Smart Nation Singapore (2023)
Governance	Establishing regulatory frameworks, public policies, and metrics to ensure accountability.	PMO (2024b)
Stakeholders	Involvement of citizens, businesses, and other key urban actors in the decision-making process.	Hämäläinen (2020)
Skills & Workforce	Upskilling of public sector and workforce to adapt to smart city developments.	Calder (2016) , Henderson (2012)
Digital Society	Ensuring digital inclusion by providing devices and internet access, especially for marginalised groups.	PMO (2024c)
Digital Economy	Encouraging digital transactions, fostering economic growth through tech innovations.	PMO (2024a)
Digital Government	Leveraging technology to improve citizen services and internal administrative efficiency.	PMO (2024b)

Source: Authors.

TABLE 3 Inclusion processes and gaps.

City	Findings	Inclusion processes	Gaps
Singapore	<ul style="list-style-type: none"> • Energy efficiency (smart grids, renewable integration) • Smart transportation (autonomous vehicles, real-time transport data) • Home and environmental monitoring • Business productivity and economic growth • Healthcare digitalization • Public sector e-services 	<ul style="list-style-type: none"> • Open Data platforms encourage innovation and start-ups. • Smart Nation Initiative focuses on digital government services and citizen engagement. • Collaboration with universities and private sector enhances tech development. 	<ul style="list-style-type: none"> • Heavy government-driven initiatives may limit grassroots-driven innovation. • Privacy concerns regarding extensive surveillance and data collection. • Potential digital divide among older populations and low-income groups
Copenhagen	<ul style="list-style-type: none"> • Citizen-centric smart governance and public participation models. • Fast broadband and mobile connectivity for digital inclusivity. • Smart energy incubators and energy labs to achieve carbon neutrality by 2025. • Smart transport systems for reducing emissions and congestion. • Open Data platforms for transparency and citizen-driven innovation. 	<ul style="list-style-type: none"> • Collaborative governance: Public-private partnerships for green energy and mobility. • Crowdsourcing and digital engagement platforms allow citizens to contribute data. • Testbed city model: Copenhagen serves as a testbed for green innovation projects. 	<ul style="list-style-type: none"> • Scalability of initiatives beyond pilot projects is a concern. • Citizen-driven initiatives lack autonomy as projects are often guided by municipal strategies. • Need for long-term funding models to sustain smart city efforts
Barcelona	<ul style="list-style-type: none"> • Integrates green technologies and digital infrastructure for sustainability. • Smart water efficiency programmes for conservation. • Participatory democracy models for citizen engagement. • Smart transportation and mobility solutions including bike-sharing and smart parking. • Entrepreneurial innovation opportunities through open databases. 	<ul style="list-style-type: none"> • Decentralised citizen engagement through participatory budgeting. • Open-source data platforms support co-creation and civic tech projects. • Public-private innovation hubs foster digital transformation. 	<ul style="list-style-type: none"> • Challenges in digital literacy among marginalised groups. • Reliance on public-private partnerships risks prioritising commercial over social interests. • Scalability and funding for grassroots initiatives remain a challenge
Zurich	<ul style="list-style-type: none"> • Advanced mobility solutions, including smart traffic management. • Data-driven environmental monitoring to reduce pollution. • Smart governance practices for efficient city services. • Strong focus on urban sustainability and smart grids. 	<ul style="list-style-type: none"> • Citizen participation frameworks integrated into governance structures. • Public-private research collaborations advance technology integration. • Data transparency initiatives allow public access to municipal data. 	<ul style="list-style-type: none"> • Challenges in integrating real-time citizen feedback into policy decisions. • Privacy and data security concerns in extensive smart surveillance networks. • Need for enhanced affordability of smart services for all income levels
Bangkok	<ul style="list-style-type: none"> • Digitalisation of public services to improve efficiency. • Smart mobility initiatives to tackle congestion and pollution. • Environmental monitoring systems to track air quality. • Use of IoT-based smart infrastructure in select pilot projects. 	<ul style="list-style-type: none"> • Top-down governance with limited citizen engagement in decision-making. • Public-private collaborations focus on infrastructure upgrades. • Government-led smart initiatives prioritise economic and industrial zones. 	<ul style="list-style-type: none"> • Limited citizen participation due to top-down approach. • Gaps in digital literacy prevent widespread adoption of smart solutions. • Insufficient open data policies hinder co-creation of smart services
Tokyo	<ul style="list-style-type: none"> • Smart transportation systems, including AI-driven traffic management. • Digital governance services for public convenience. • IoT and AI deployment in environmental monitoring. • Smart living solutions, such as energy-efficient homes. 	<ul style="list-style-type: none"> • Government-backed urban innovation policies drive tech adoption. • Collaboration with academia and private sector to advance smart technologies. • Pilot projects allow incremental implementation of solutions. 	<ul style="list-style-type: none"> • Digital inequality in ageing populations who struggle with smart services. • Lack of flexible citizen engagement frameworks beyond structured government-led initiatives. • Challenges in balancing technology-driven planning with community needs

Source: Author. [Kaluvarachchi \(2022\)](#).

was required. This process was lengthy but enabled some record-keeping in case of infection detection ([Tan and The Straits Times Covid-19 Team, 2022](#); [Ong, 2022](#)).

3.1 Smart city success factors

A study on digital transformation in Helsinki found that several essential factors in the smart city framework consist of four

dimensions: strategy, technology, governance, and stakeholders ([Hämäläinen, 2020](#)). With the plan in place, the city will define its vision and execution methods while utilising governance to establish metrics for managing progress and funding. The stakeholders include citizens and businesses that depend on the city's offerings and infrastructure. Therefore, ensuring that the value offering aligns with stakeholders' expectations is essential. The process involves innovative solutions and data collection to manage

and monitor the services or solutions planned for the city's growth (Hämäläinen, 2020).

Early in its city development journey, Singapore recognised the need to upskill public sector staff (Calder, 2016). The vision for a green city and effective water resource management established foundational skills strategies. Additionally, the redevelopment of the city and the digitisation of the public sector contributed to a long-term vision for skills development (Henderson, 2012). The initial vision and strategies set the stage for Singapore's success as a Smart Nation, which has been a challenging journey involving many adjustments, ultimately narrowing focus to key areas such as urban living, transport, education, and health (Singapore Computer Society, 2020). The Smart Nation initiative (Smart Nation Singapore, 2023) has identified three pillars for developing solutions and services in Singapore: the "Digital Society," "Digital Economy," and "Digital Government."

One of the most critical factors contributing to a successful smart city initiative is strategic vision and governance. Cities such as Helsinki and Singapore have demonstrated how structured planning, regulatory frameworks, and stakeholder involvement facilitate long-term success (Hämäläinen, 2020).

Another essential component is integrating technology, where smart solutions such as IoT, AI, and big data monitor and optimise city functions. Singapore's Smart Nation initiative has extensively utilised technology to enhance urban living (Smart Nation Singapore, 2023).

Additionally, upskilling in the public sector and engaging citizens are vital. Singapore recognised early on that developing skills in both the workforce and citizens would be essential for sustaining a smart city (Calder, 2016; Henderson, 2012). Similarly, efforts towards digital inclusion ensure that the advantages of a smart city reach all demographic segments, mainly through targeted subsidy programmes (PMO, 2024c).

3.2 Citizen participation

Public-private partnerships (PPPs) have long been integral to public sector strategies for developing innovative solutions. These collaborations often require ongoing maintenance and operational support, allowing the public sector to leverage private sector expertise. A crucial component of such partnerships is the implementation of data collection and open data strategies, which have been shown to drive innovation (Sulistia and Nam, 2022). However, despite the recognised benefits of open data, gaps remain in understanding how varying levels of data accessibility influence the effectiveness and scalability of smart city initiatives.

A comprehensive approach to data collection is essential, encompassing diverse public services such as transportation, energy, waste management, and water infrastructure. Establishing a robust local government framework to support future advancements in data analytics is fundamental for optimising urban development. Prior research highlights that one of the key drivers for successful smart city initiatives is adopting an open data framework (Sulistia and Nam, 2022). In this regard, private sector entities play a critical role, often collecting vast consumer data. Certain private organisations, such as Grab, have begun to share their data with the public sector as an open data service, benefiting the public interest. Nevertheless, further research is required to assess how private-sector data-sharing initiatives contribute to long-term urban development and the challenges associated with data governance.

Financial sustainability is a crucial factor in ensuring the long-term viability of smart city projects. Stakeholders must address financial security to enable sustainable project deployment and create enduring value (Kong et al., 2021). However, existing literature lacks comprehensive case studies that examine how various financial models influence the sustainability of smart city initiatives over extended periods.

A study by Kaluarachchi (2022) analysing 50 cities worldwide underscores the diverse approaches taken by various urban centres in implementing smart city strategies. For example, Singapore prioritises energy efficiency, transportation, environmental sustainability, business productivity, healthcare, and public sector services. Meanwhile, Copenhagen focuses on citizen participation, technological infrastructure, broadband connectivity, smart energy incubators, and open data platforms to achieve carbon neutrality by 2025. While these cases provide valuable insights, a gap remains in cross-comparative analyses that assess the effectiveness of different smart city engagement models and their socio-economic impacts.

Citizen engagement is a pivotal component of smart city development. In Singapore, the government has initiated programmes such as the Smart Nation Ambassadors, where volunteers assist citizens—particularly senior populations—in navigating digital services (Smart Nation Ambassadors, 2023). Despite these efforts, there is limited empirical research evaluating the long-term effectiveness of such volunteer-driven engagement models in bridging the digital divide. Similarly, various countries leverage social media platforms to collect public feedback on urban initiatives (Simonofski et al., 2021). Singapore, for example, monitors citizen perspectives through Twitter, Facebook, and other digital platforms, integrating this data into policymaking (MOF Singapore, 2018). However, there is still insufficient research on the reliability, biases, and ethical implications of utilising social media as a primary tool for public engagement in urban planning.

Singapore Smart Nation uses citizen inclusion in the smart nation agenda by involving citizens in co-creating solutions, providing them with digital access and skills, and ensuring their trust and participation (Smart Nation Engagement Programmes, 2023). Some examples from the Smart Nation website are:

- a) "The Smart Nation Co-creating with our People Everywhere (SCOPE) initiative. To engage citizens through workshops, surveys, and focus groups to gather feedback and ideas on improving public services and policies using technology."
- b) "The Digital Inclusion Fund supports programmes that help low-income households, seniors, and persons with disabilities to access affordable devices, broadband connectivity, and digital literacy training."
- c) "The Smart Nation Ambassador Program recruits volunteers to promote digital adoption and awareness among their peers and communities."
- d) "The National Digital Identity (NDI) system provides citizens with a secure and convenient way to verify their identity online and access various government and private sector services."
- e) "The Smart Nation Sensor Platform (SNSP) deploys a network of sensors and cameras across the island to collect data on traffic, environment, security, and other urban issues. The data is anonymised and aggregated to protect the privacy and shared with citizens through the OneService app and Data.gov.sg."

While smart city initiatives show promising advancements in technology integration, open data utilisation, and citizen engagement, several critical research gaps persist. Future studies should assess the long-term impact of data sharing between the public and private sectors, the effectiveness of financial models in sustaining smart city projects, and the socio-economic outcomes of various citizen engagement strategies. Addressing these gaps will enhance our comprehensive understanding of how Smart Cities can be effectively developed and managed in the future.

3.2.1 Data-driven smart cities and citizen inclusion

Kaluarachchi (2022) describes data-driven smart city applications for future cities and addresses how a data-driven smart city approach leverages advanced technologies such as IoT, AI, Big Data, and Open Data to enhance urban governance, mobility, environmental sustainability, economic growth, and quality of life. This approach enables cities to optimise services, improve efficiency, and foster innovation. However, the success of smart cities relies not only on technology but also on citizen inclusion—ensuring that residents actively participate in decision-making, have access to digital services, and benefit equitably from technological advancements.

Citizen inclusion in smart cities can take various forms, including participatory governance models, open data platforms, crowdsourcing initiatives, and digital literacy programmes. While some cities excel in engaging their residents in shaping urban policies, others still struggle with top-down governance, digital divides, and data privacy concerns.

The table below summarises findings from six major smart cities—Singapore, Copenhagen, Barcelona, Zurich, Bangkok, and Tokyo—highlighting their data-driven initiatives, inclusion processes, and existing gaps.

Despite significant technological advancements, smart cities face several ongoing challenges that hinder their long-term success and inclusivity. One of the most critical issues is the digital divide, which often affects elderly and low-income populations who struggle to access and benefit from digital services. This gap limits their ability to engage with smart city infrastructures, ultimately diminishing the overall effectiveness of digital transformation initiatives. Research indicates that digital inclusion can bridge this divide and reduce social exclusion among older adults, thereby enhancing their quality of life (Yang et al., 2022).

Another major concern is privacy and data security, as the increasing reliance on real-time data collection and surveillance raises significant ethical questions regarding citizens' rights and personal data protection. Many smart cities depend on extensive data-driven monitoring systems; however, the governance structures necessary to ensure transparency and accountability in data usage often remain underdeveloped. Studies have highlighted negative outcomes for personal privacy and information security stemming from current smart city development programmes, emphasising the insufficiency of existing legal and practical remedies (Fabrègue and Bogoni, 2023).

Furthermore, limited grassroots involvement presents a significant challenge to sustainable urban innovation. Many smart city projects are mainly government-led or heavily influenced by private sector stakeholders, leaving little space for community-driven participation. This top-down approach can lead to a lack of localised innovation, potentially leading to smart city solutions that do not adequately address the needs and preferences of the general

population. Research into authentic citizen participation practices suggests that promoting active involvement through a rights-based approach can enhance participation, making it more equitable, inclusive, and sustainable (Kumar, 2024).

Scalability and funding complicate the sustainability of smart city initiatives. Although many cities successfully launch pilot projects, transitioning from initial implementation to large-scale, long-term integration remains challenging. Limited financial resources and the need for continuous technological updates and maintenance impose significant constraints on expanding smart initiatives beyond their initial phases. A comprehensive survey on the societal aspects of smart cities highlights the importance of addressing these challenges to successfully scale smart city projects (Bastos et al., 2024).

Ultimately, the balance between commercial and public interests remains a crucial factor in shaping the trajectory of smart city development. In some instances, economic and commercial priorities take precedence over social inclusion, resulting in policies and projects that favour profitability rather than equitable urban development. Without a framework that balances technological advancements with social equity, smart cities risk exacerbating existing socioeconomic inequalities instead of improving them. Smart cities highlight the necessity for governance models that provide public value and equal benefits for all (Kolotouchkina et al., 2024).

A more integrated and citizen-centric approach is necessary to ensure the long-term success of smart city initiatives. Future developments must emphasise inclusive digital accessibility, participatory governance, and transparent policy frameworks to foster equitable urban growth. By addressing these challenges, smart cities can fully realise their potential in creating sustainable, innovative, and socially responsible urban environments.

3.3 Case study: how Singapore implemented TraceTogether to monitor COVID-19 spread

This study uses the TraceTogether app^{1,2} as a case study of Singapore's urban innovation process. The evidence gathered from the app's launch to the halt of contact tracing, combined with citizens' experiences, shows that Singapore effectively handles a crisis through organisation and expertise. Furthermore, the ability to employ innovative technology has facilitated monitoring the spread of COVID-19 infections and ensured safe access for its citizens.

The TraceTogether app was developed by engineers from the Singapore Government Technology Agency (GovTech) as a solution to collect location data more efficiently and assess infection risk during the COVID-19 pandemic. The development team collaborated with the Ministry of Health (MOH) to create a data exchange platform prioritising personal data security. The aim was to identify potential contamination risks if a known risk carrier

1 Repository for IOS TraceTogether source code <https://github.com/GovTechSG/OpenTT-iOS>.

2 Repository for Android TraceTogether source code <https://github.com/GovTechSG/OpenTT-Android>.

came into contact with others. The app allowed authorities to review the location history of infected individuals and contact anyone who may have crossed paths with them during a specified timeframe (Tan et al., 2022). Figure 2 illustrates how the TraceTogether app was developed by the Singapore Government Technology Agency (GovTech) engineers, who, through some innovation exercises, came up with a solution to collect location data more efficiently and use the collected data to detect transmittable infection risk during COVID-19. The team worked with The Ministry of Health (MOH) to design a data exchange platform that lowers the risk of personal data security. At the same time, the goal was to detect possible contamination risk if a risk carrier crossed paths with other individuals. This was used to look back at past location history for an infected patient and contact every person who may have crossed paths during a past period of time (Tan et al., 2022).

Some feedback measures used included citizens' usage of the apps and opinions posted on social media. Selected groups of citizens were interviewed, and GovTech staff advised and trained them to utilise the apps. Additionally, Smart Nation established a citizen task force known as Ambassadors. The Ambassadors engaged with other citizens to assist during app upgrades, vaccinations, or even in malls and public places.

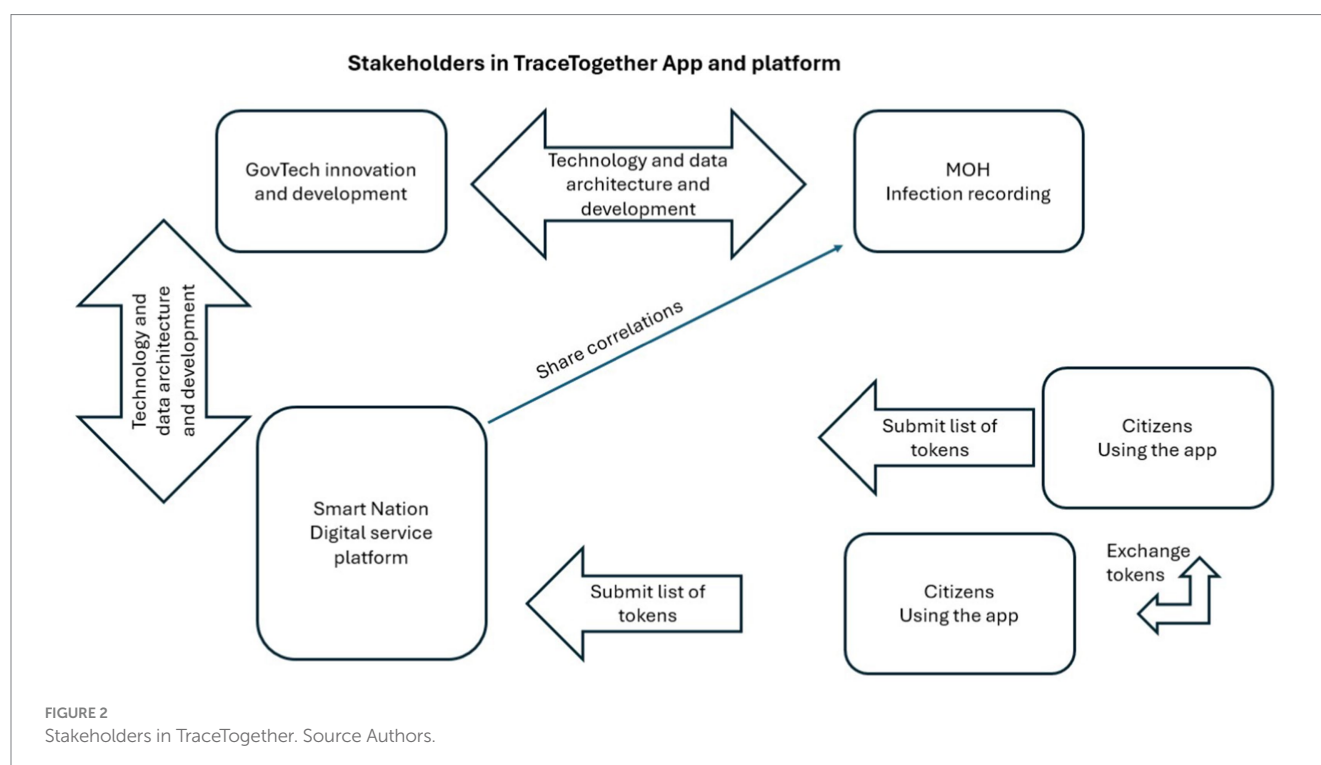
3.3.1 TraceTogether architectural design

To monitor infections and trace the virus among the population in Singapore, the government implemented a manual registration to monitor entrance in buildings. This became a complicated process, and it was difficult to follow up when an infection case was detected. The TraceTogether app simplified this process and made it easier to treat individuals at early infection stages proactively (<https://www.smartnation.gov.sg/files/press-releases/2021/data-safeguard-infographic.pdf>).

The technology is an open-source platform called Herald, which supports Bluetooth tracing. The Singapore government donated the source code as open source to make it globally available (Fowler, 2021; Bay, 2022). The security advantage of the app lies in its use of Bluetooth technology to identify when one person is near an infected individual. It then alerts the user with a notification in the app. The app uses anonymous IDs exchanged between smartphones when proximity is detected. The data is stored on the mobile device and is automatically deleted after 25 days (Alanzi, 2021).

The TraceTogether dataset was defined using a randomly generated ID. Unlike similar solutions in other countries that collected GPS locations (Stevens and Dunnage, 2020), the TraceTogether app only collects unique IDs created for the mobile device. Upon registration, this ID is linked to the user's mobile and social security numbers (see Figure 3). The mobile and social security numbers are stored on a secure server, enabling the Ministry of Health to identify and contact the individual in case of infection. If a person is infected, this phone call will be followed up with questions about the locations the person has visited to gather similar statistics from other infected individuals (TraceTogether, 2021). Only the randomised ID is exchanged between devices, and no GPS information is collected, ensuring a more secure dataset. No one can link the randomised data ID to an individual. No other personal information is provided or stored locally on the mobile device (Oliveiro, 2021; GovTech, 2020a).

The digital solution supporting TraceTogether also includes additional services linked to it, such as the SafeEntry system, which registered citizens at venues using a QR code. Health Certification was issued for travellers, providing a QR code that customs checkpoints could use to verify vaccination statuses. Other healthcare services were also connected to the system.



TraceTogether data architecture

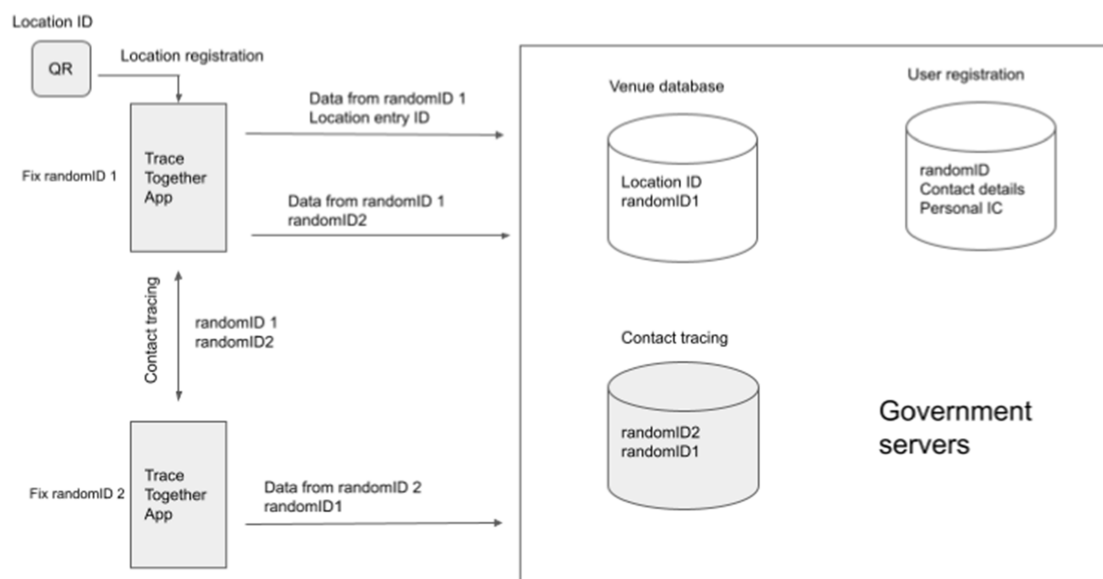


FIGURE 3
TraceTogether data architecture and flow. Source: Authors.



FIGURE 4
The TraceTogether token. Source: GovTech (2023).

3.3.2 TraceTogether usage and experiences

Some citizens did show privacy concerns about the data collected from the TraceTogether platform. This concern emerged after Dr. Vivian Balakrishnan, the minister in charge of the Smart Nation initiatives, announced that the “data would only be used for contact racing purposes” (Tan and The Straits Times Covid-19 Team, 2022, p. 95). However, by January 2021, over 4.2 million people, or 78% of the population, were using TraceTogether (Yuen, 2021).

The continuous engagement with communities enabled the team to improve TraceTogether and introduce Bluetooth tokens, see Figure 4 (Bay, 2022), as many senior citizens had difficulties using smartphones. This also inspired further improvements in the user

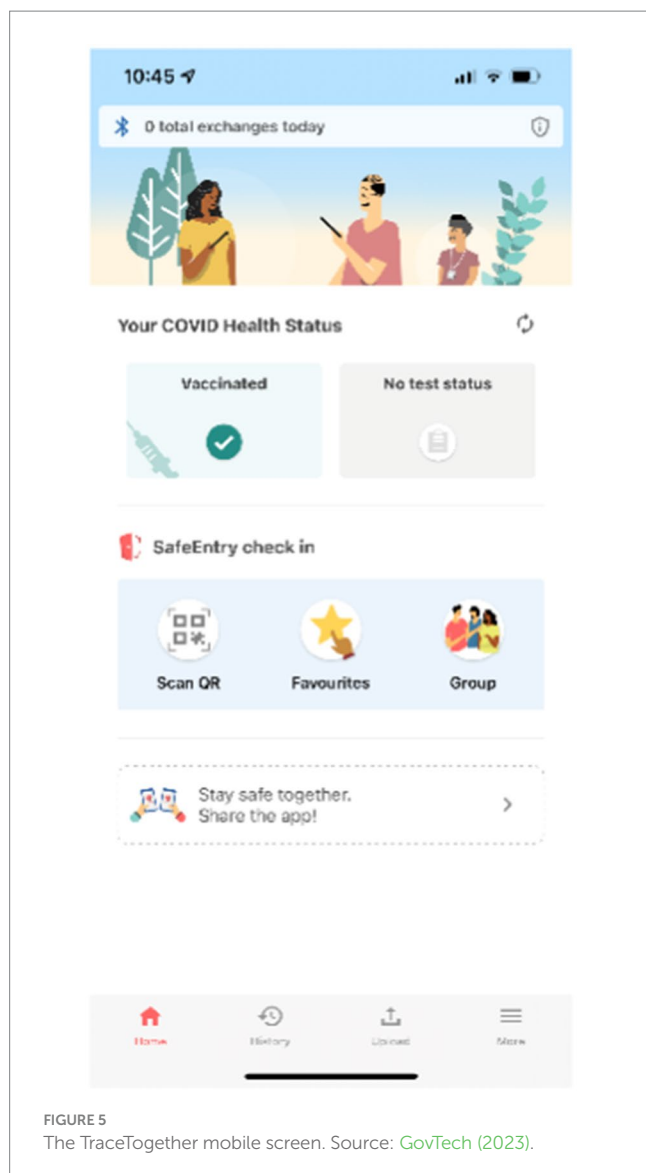
experience of the TraceTogether app (GovTech, 2020b). The Bluetooth token came with a 4–6 months battery lifespan. It provided a better sense of health and security among senior citizens who did not have digital skills or mobile devices to use the TraceTogether app. Volunteers were chosen to assist the elderly and individuals with technological disadvantages. They guided citizens on how to use devices, and in malls and supermarkets, volunteers were available to help people register their entry during the restricted lockdown periods.

The TraceTogether mobile app underwent several iterations of UI/UX design to provide citizens with a more seamless experience when using the app and to gain an overview of potential risks through contact tracing (Figure 5). The TraceTogether token, as described above, could be used for up to 6 months before the battery needed replacement. This service was offered through community centres in Singapore, where temporary staff or volunteers assisted citizens with their tokens.

3.3.3 Experiences

The Ministry of Health published daily COVID cases with location information during the pandemic. This was part of bringing awareness to the population and ensuring a focus on tackling the spread. With all the data being shared daily, some citizens took the time to analyse the data and provide some visualisation of the COVID cases in Singapore (Chua, 2021). The interactive visualisation can be viewed on a public version of Tableau; see Figures 6, 7.

The data collected for visualisation are similar to how TraceTogether collects data in real time. According to the news report, citizens watch the news and test themselves to see if they visited any locations during the reported periods. The advantage of TraceTogether is that the app automatically notifies citizens if they pass an individual



who has reported testing positive or has been reported from the clinic or hospital.

The sample extracted from the collected data illustrates the cases and location on May 9, 2021. The red areas (Figure 7) show seven cases in each of the location collections. On that date, 170 locations and 231 cases were reported.

3.4 Comparing Singapore's TraceTogether with global smart city COVID-19 initiatives

Singapore's TraceTogether programme is a pioneering digital contact tracing (DCT) initiative designed to mitigate the spread of COVID-19 through Bluetooth-based proximity tracking. While this approach has demonstrated effectiveness in early detection and containment, it is essential to compare it with other global smart city initiatives. This section examines the strengths, weaknesses, and

broader implications of Singapore's strategy for international counterparts, considering factors such as technological infrastructure, citizen engagement, privacy concerns, and policy effectiveness.

3.4.1 Technological infrastructure and adoption

Singapore's TraceTogether, launched in March 2020, was among the first government-backed DCT applications. It leverages mobile applications and Bluetooth-enabled tokens to track user interactions. Adoption was significantly driven by regulatory mandates, including a requirement for entry into public spaces (Chow et al., 2023). However, despite an initial high uptake (over 90% of the population), adoption challenges persisted due to public scepticism about data privacy (Tan and Lim, 2022).

In contrast, South Korea's strategy integrated mobile GPS data, credit card transactions, and CCTV footage to reconstruct movement patterns (Sonn et al., 2020). This multi-source approach enhanced accuracy in contact tracing but also raised privacy concerns. The United Kingdom and Germany employed decentralised, privacy-preserving DCT apps based on the Apple-Google Exposure Notification framework (Esposito et al., 2021), avoiding mandatory participation while achieving moderate voluntary adoption.

3.4.2 Effectiveness and success rates

The effectiveness of DCT initiatives varies based on implementation strategies. Singapore reduced contact tracing time by approximately 34.9% compared to manual methods (Chow et al., 2023). However, manual tracing remained more accurate in identifying positive cases among close contacts.

South Korea demonstrated a high success rate by incorporating a layered approach, integrating DCT with human epidemiological tracing. While ensuring privacy protection, the UK and Germany struggled with lower adoption rates, reducing the overall impact of their apps (Esposito et al., 2021).

3.4.3 Citizen engagement and trust issues

Singapore's top-down governance model facilitated quick deployment but faced resistance due to data privacy concerns. A survey found that while 92% of citizens were aware of TraceTogether, only 49% consistently used it (Huang et al., 2021). Public perception worsened when it was revealed that TraceTogether data could be accessed for criminal investigations despite earlier government assurances of exclusivity for public health use (Tan and Lim, 2022).

Conversely, South Korea and Taiwan communicated openly about their data governance policies, fostering greater public trust. In contrast, Western democracies, particularly in Europe, emphasised privacy but faced adoption challenges due to voluntary participation models (Esposito et al., 2021).

Singapore's gaps:

- Privacy concerns: Transparency issues regarding government access to data led to declining public trust.
- Over-reliance on one technology: Unlike South Korea, which used multiple data sources, Singapore depended primarily on Bluetooth tracking.
- Engagement Strategies: A transactional communication approach led to resistance instead of fostering trust (Tan and Lim, 2022).

COVID count June 2020 until July 2021

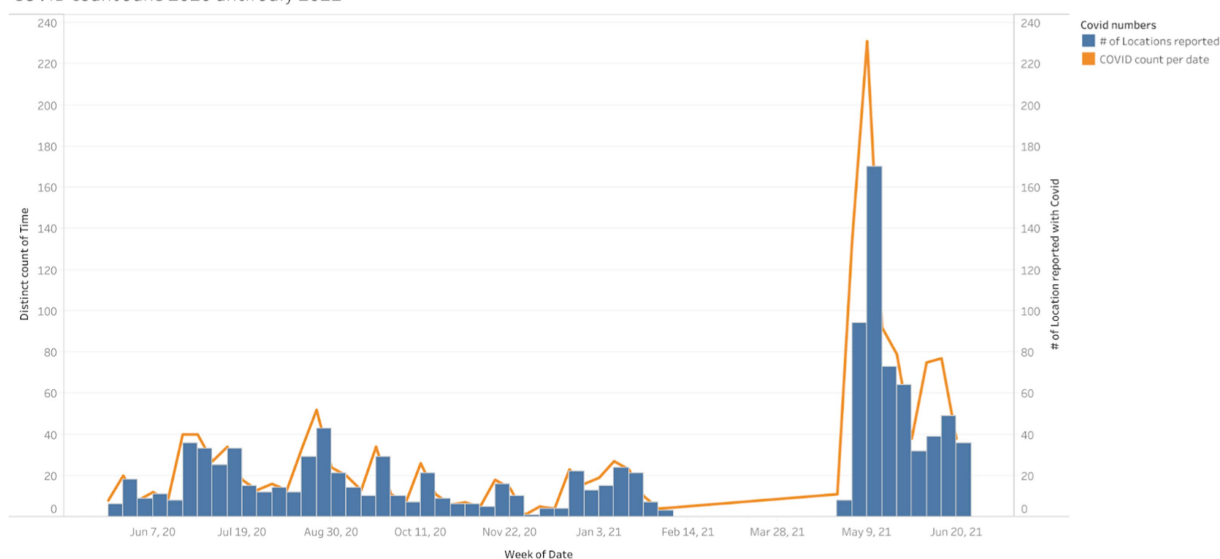


FIGURE 6

Covid number per location over time. Source: data from Chua (2021), visualisation by authors.

Singapore COVID Spread Timelapse - 9 May 2021

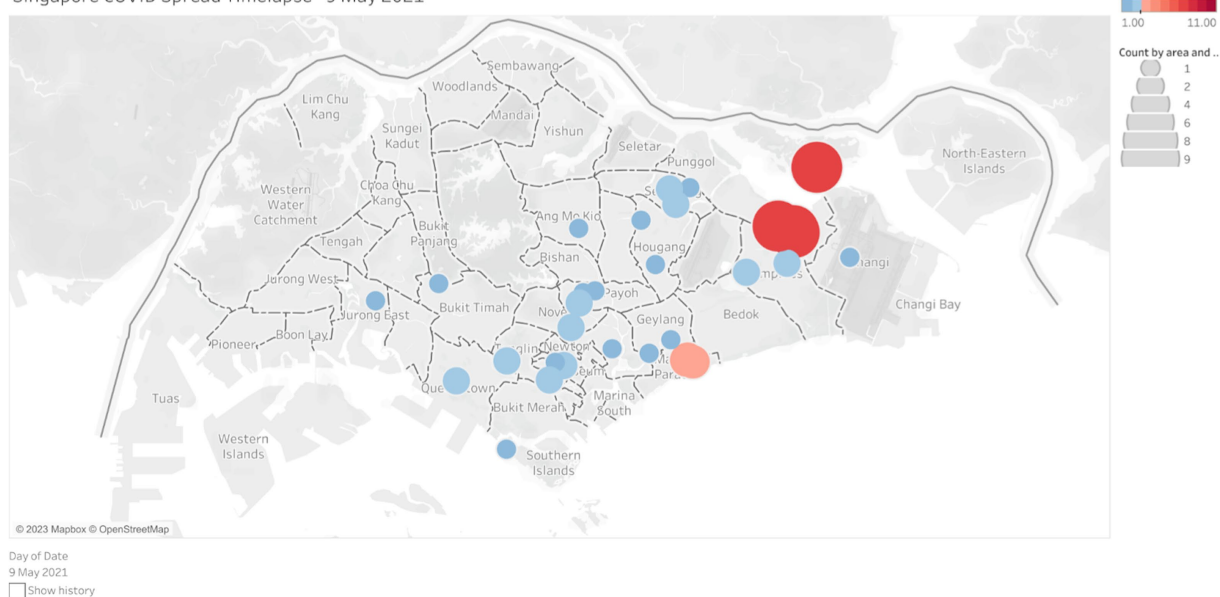


FIGURE 7

COVID cases in Singapore on May 9, 2021. Source: Chua (2021), Public Tableau viz.

Global gaps:

- Efficiency vs. privacy trade-offs: While European nations prioritised privacy, adoption rates suffered, limiting effectiveness.
- Scalability issues: Some countries struggled with integrating digital solutions into broader health infrastructure, delaying response times.

- Dependence on voluntary adoption: Countries with voluntary models, such as the UK, faced lower compliance and reduced effectiveness.

Singapore's TraceTogether set a benchmark in digital contact tracing with strong adoption and regulation. However, public distrust and over-reliance on one technology were limiting. In contrast, South

Korea and Taiwan succeeded by integrating multi-source data and fostering public trust through transparency. European nations faced challenges balancing privacy with adoption. Future smart city health strategies should prioritise privacy-preserving, transparency and effective multi-faceted solutions to ensure public trust and epidemiological efficacy.

4 Materials and methods

This study employed a mixed-methods approach, combining a literature review, empirical data collection, and a case study analysis. The study aims to contribute to the knowledge of the factors that lead to successful smart city projects with citizens’ participation and identify such projects’ value propositions.

The research design diagram (Figure 8) outlines a structured approach for investigating the factors contributing to successful projects in the context of smart cities. It employs a multi-method strategy combining literature review, case studies, interviews, and surveys to gather data.

4.1 Data collection methods

The research utilises a combination of literature reviews, case studies, interviews, and surveys to gather diverse insights into smart city projects. The literature review examines existing theoretical and empirical studies to establish a foundation for analysis. Case studies offer in-depth examinations of specific smart city implementations; in this case, the focus is on the TraceTogether app, which provides practical insights. Interviews involve key stakeholders, including policymakers, urban planners, and members of the Smart Nation team, to understand

their perspectives. Additionally, surveys collect quantitative data from a broader population to validate findings and identify trends.

4.2 Analytical framework

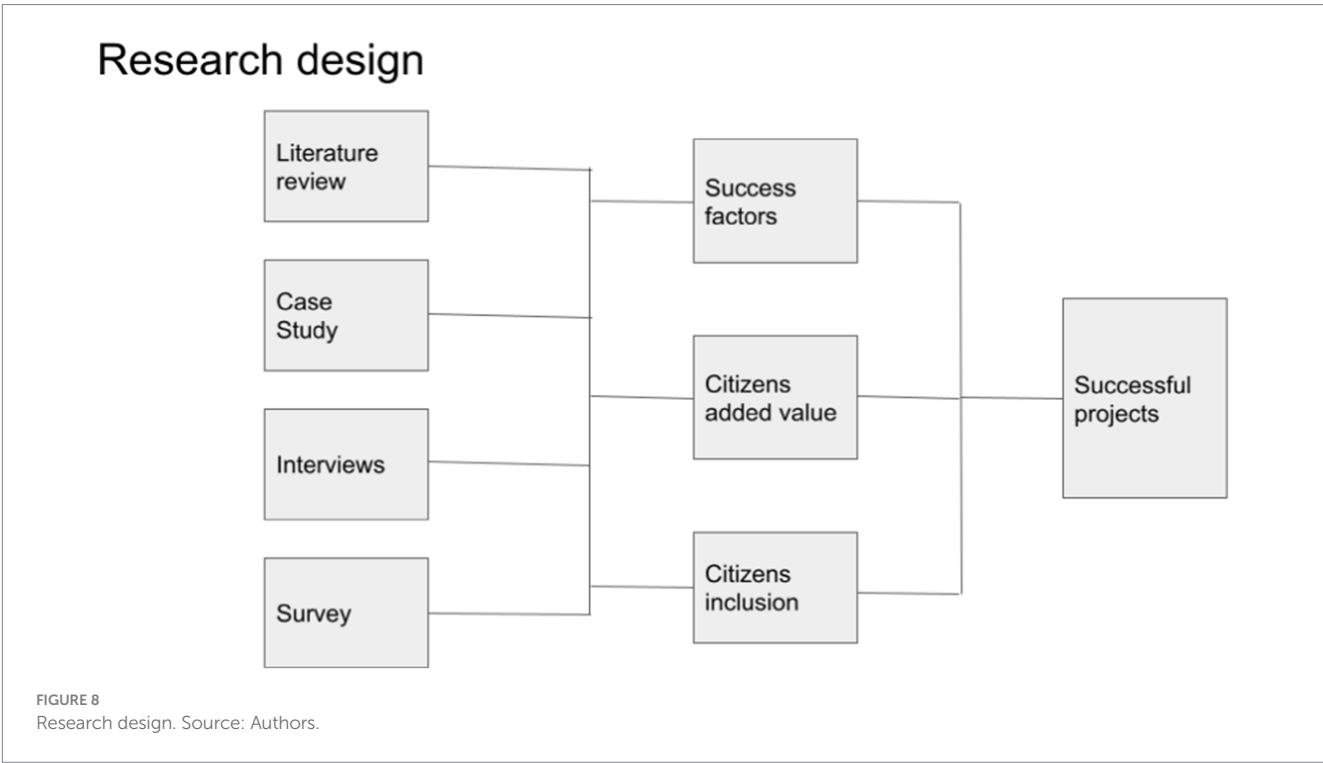
The study focuses on three core analytical dimensions: (i) Success factors that determine the key elements contributing to the effectiveness of smart city initiatives. (ii) The added value of citizen participation is examined to understand how community involvement enhances project outcomes. (iii) The level of citizen inclusion is analysed, assessing the extent to which communities are engaged in decision-making processes and their overall impact.

4.3 Success factors

Several key factors influence the success of smart city projects. Effective governance ensures efficient decision-making, policy implementation, and stakeholder collaboration. Technological innovation enhances infrastructure, connectivity, and service delivery, making urban environments more efficient. Citizen engagement fosters trust, participation, and co-creation, creating more inclusive and sustainable solutions. Financial sustainability ensures long-term project viability by securing investments and funding sources. Additionally, scalability and adaptability allow smart city initiatives to evolve in response to changing societal and technological demands.

4.4 Outcome

The study aims to identify the conditions and best practices that lead to successful smart city projects. The findings provide



valuable recommendations for policymakers and urban developers, ensuring that governance, technology, and citizen engagement are effectively integrated. By adopting this holistic approach, the research contributes to a deeper understanding of how smart cities can be developed and managed for long-term success.

The factors contributing to the success of smart city projects with citizens' participation and identify the value proposition of successful projects given by the main research question:

- **RQ1.** Why do smart city projects succeed with citizens' participation? And what factors define the value proposition of the successful project?

To address this research question, the study was guided by two sub-questions:

- **RSQ1:** What factors lead to the success of smart city projects?

To answer this sub-question RSQ1, a literature review was conducted to identify the critical success factors of smart city projects. The review was based on academic articles, reports, and case studies on smart city projects with citizens' participation. The review considered technological innovation, stakeholder engagement, governance, economy, and sustainability. The identified factors were used to develop a conceptual framework for analysing successful smart city projects.

The literature review analysed academic articles, reports, and case studies on smart city projects with citizens' participation. It began by searching relevant academic databases such as Google Scholar, Elicit.org, JSTOR, and Science Direct, using keywords such as "smart nation," "citizen participation," "success factors," "TraceTogether," and "governance."

The inclusion and exclusion criteria were based on the relevance of the articles, reports, and case studies to the research question and sub-questions. At the same time, reports and case studies were sourced from reputable institutions such as the World Bank, the United Nations, and local government authorities. The selected articles, reports, and case studies were screened, and only those that meet the inclusion criteria will be included in the literature review.

Overall, the literature review provided a comprehensive understanding of the factors that led to the success of smart city projects with citizens' participation. It also helped identify gaps and limitations in the existing literature, guiding the empirical data collection and analysis.

- **RSQ2:** What value do citizens add to smart city projects that succeed?

To answer the sub-question RSQ2, empirical data was collected through in-depth interviews with city stakeholders and surveys with citizens who had participated in successful smart city projects. The study was conducted in Singapore, a city-state at the forefront of smart city development, with several projects incorporating citizen participation. In this study, we focused on one solution that Smart Nation launched and operated during the global pandemic between 2020 and 2022: the TraceTogether App. The sampling strategy involved

sampling city stakeholders, such as government officials and private sector partners, and monitoring successful smart city projects in Singapore.

The selection of stakeholders was guided by recommendations from the Smart Nation Team, ensuring that key representatives directly involved in Singapore's digital transformation efforts were included. The 10 stakeholders interviewed were drawn from urban planning, digital governance, technology development, and project management—critical domains that shaped the implementation of Smart Nation initiatives. Citizens were selected for interviews to understand their perceptions of the Smart Nation. They were chosen based on their Citizenship or Permanent Resident (PR) status, long-term residence in Singapore, and use of public service solutions or services. During the interview process, some stakeholders were willing to meet several times and discuss further based on discoveries or questions related to the study.

Stakeholders were chosen based on their roles, responsibilities, and expertise in the projects being investigated, particularly those related to digital services and large-scale technological implementations. The selection process prioritised individuals with firsthand experience in policy formulation, technical deployment, and operational oversight to offer a comprehensive perspective on Singapore's Smart Nation strategies.

The stakeholders interviewed included: (i) Urban Redevelopment Authority (URA) representatives who provided insights into integrating smart city solutions in urban planning. (ii) Smart Nation Team members offered perspectives on national policies, governance, and digital transformation strategies. (iii) Technical Staff—provided technical expertise on designing, developing, and deploying smart solutions. (iv) Management Staff who oversaw the TraceTogether app rollout—shared experiences on the challenges and best practices in implementing a large-scale public health technology initiative. (v) Management Staff from ST Engineering—contributed with industry insights on smart infrastructure, security, and technological innovation.

For the citizen survey, a random sampling technique was employed to select participants from the population of citizens who utilised the TraceTogether app during the pandemic in Singapore. The survey was conducted online and through in-person engagements. Participants were recruited via social media and online forums. The survey included both open-ended and closed-ended questions that gathered information on the benefits of citizen participation in using the TraceTogether app.

The interviews with city stakeholders were summarised using a semi-structured interview guide. The survey data, which provided a sample size of 148, was analysed using descriptive statistics, such as frequencies and percentages, and sentiment analysis to identify the values citizens add to smart city projects.

The qualitative data collected from the interviews provided insights into the stakeholders' perceptions of project successes, and the surveys were analysed using statistical methods. The study involved identifying themes and patterns in the data, which were used to develop a conceptual framework for examining factors influencing successful smart city projects. The analysis focused on the benefits of citizen participation, including increased social inclusion, improved urban innovation, and enhanced service delivery.

5 Results and discussion

The results and discussion section is organised into three subsections: 5.1 discusses the results derived from the semi-structured interviews; 5.2 addresses the survey data, which includes sentiment analysis; and 5.3 consolidates the findings related to the success factors identified in the study.

5.1 Results of semi-structured interviews

The semi-structured interview sessions covered the smart city vision and understanding of the focus on innovation and inclusion with projects and strategies. Figure 9 illustrates the focus area of the semi-structured interview sessions. The green area reflects the discussions on citizen inclusion, and the yellow area reflects the discussions on innovation. The ranking suggested that citizens' inclusion was focused on the categories of people and economy, where innovation benefits were concentrated within the economy and governance.

The interview with the Urban Redevelopment Authority (URA) was conducted with a director for digital planning, who gave a brief overview of how Singapore started in the 1960s to plan and improve its areas. The urban planners were educated overseas to develop as much international knowledge as possible in the government-built Singapore. The planning activity started as city planning and has extended to all areas of Singapore. Over the years, technology and digitisation have been adopted as urban planning tools.

The pioneers planning Singapore's urban landscape brought inspiration and ideas from overseas. Digital tools became more critical and valuable later. From 2013, when Singapore boosted urban development, managing the many developers, planning the development, and prioritising the different areas became essential. As requests and activities grew, finding a solution for many requests and projects became relevant. This resulted in developing an internal tool

for mapping projects in Singapore, which meant that information had to be digitised to progress and continuously manage the projects. The director emphasised that smart city projects are large and complex. The project scope's important part was identifying the value these projects would bring before pouring in millions of dollars of investment. He also clarified that for the government to manage and support smart city projects, it is essential to build internal expertise and tools. As he mentioned "Singapore has built up knowledge and launched smaller projects to better prepare for integration in the future." All cities should prioritise solving their immediate problems. One example was infrastructure fragmentation. All cities have infrastructure and mobility issues, which should be solved according to the individual city's current situation and vision.

In Singapore, they started to collect data from transport systems, including Mass Rapid Transport (MRT), buses, and taxis, as well as ride-hail services like Grab. A team within URA was trained in data analytics and worked on analysing traffic flow and people's travel habits. The data supports evaluation and planning for the location of the business, more precisely, the relocation of companies from the Central Business District (CBD) area to reduce the traffic flow into the central region, provide more convenient travel for the employees and make activities, such as piano lessons and more available in the communities.

The introduction of digitisation of urban data has made it possible to restructure processes to become more efficient. Such improvement supports the work effort to provide more accurate feedback and reduce the cost in the long run. For example, the Master plan review is incorporated into the digital system, making it easier for various parties to quickly access and review the updates on a map with references.

The URA sets up internal Hackathons on the innovation part, where teams consisting of planners, architects, and analysts get to look at policies and evaluate the data they have available from the system to explore how to align with policies. These sessions can last up to 3 months and are expected to provide the individuals with a learning process on data analytics while bringing ideas and solutions.

The second and third semi-structured interview sessions with the URA included a technology team describing the OneMap platform³ for the Smart Nation (SLA, Singapore Land Authority, 2024). During this session, the team shared how they envisioned developing a solution that provided value to the citizens, businesses, and the various public sectors. The different data collection that the URA is working with is processed by the technology teams and formatted in a model that can be used to make sense of defined scenarios—for example, mobility data, educational institution registration, graduation, power consumption, or waste management.

The URA team acknowledged that some individuals need help understanding and using the services or apps available regarding digital services design. This is an area they believe should be addressed in some way. The URA data collection supports apps, such as parkingSG, designed to handle parking payments for parking lots at street level, replacing coupon-based parking. Other parking-related apps use URA data to show parking house locations in Singapore. An interesting remark that the URA team shared was the information about an innovation platform from the Information Media Development Authority (IMDA). This platform enables small businesses to solve



³ <https://www.onemap.gov.sg/>

problems or challenges launched by the Smart Nation teams. When a business submits its solutions, and the solution works and solves the problem, the company can be contracted to tender and further work on the project. Moreover, the government has set up an accreditation programme for companies to prepare themselves to deliver high-quality solutions focusing on security. This programme also enables companies to access more opportunities from the public sector.

The Smart Nation team shared Smart Nation's current plans, focusing on the digital economy, the digital government, and the digital society. With these, the Smart Nation is set to improve businesses through digital transformation, create new jobs, develop digital public services and policy-making, and make convenient and connected communities.

The Smart Nation is managed under the Prime Minister's Office, where the work on policy-making and digital government support better governance on the Smart Nation journey. They explained that the three key enablers for building the Smart Nation are "Sharing and usage of data," "manpower and talents" and "citizens engagement." As ideas and projects are being launched, engagement with the citizens is essential to understanding citizens' perspectives. Some of the active projects in Singapore are (a) National Digital Identity, (b) E-Payments, (c) Smart Nation Sensor Platform, (d) Smart Urban Mobility, (e) Smart and Sustainable Punggol, (f) Moments of Life, (g) GoBusiness, (h) CODEX: Re-Engineering the government.

Other Smart Nations focus areas include National Digital Identity and the Smart Nation Sensor Platform. The discussion concerned citizens' usage of the national ID app, which is used by more than 3.5 million users in Singapore (Singpass, 2023) as of 2022. The SingPass App is also designed to display a digital copy of the ID for the individual and manage a two-factor website or app access on government websites. Singapore residents must use the app to access, for example, tax information on iras.gov.sg, health information on the HealthHub App, safe entry check-in to buildings during the COVID-19 pandemic, and more.

SingPass went into beta in 2018, where the features compared to previous versions were improved to provide a better user experience. Like the SingPass, the National Digital Identity platform hosts the CorpPass, a corporate digital ID for businesses. The residents also have access to the MyInfo app, which holds personal details about the residents. The individual can then use this to share with relevant parties, such as insurance businesses or banks. One of the latest developments is to perform digital signatures using the SingPass app.

The Smart Sensor platform is a long-term strategy and development, where the Smart Nation team is building a platform that will serve as the back-end service for sensor solutions in Singapore. The platform collects data from sensors in traffic and community locations, such as cameras, flood sensors, air quality and temperature, and more. Third-party usage of the platform will be expected to be used to manage their IoT and sensor solutions. The initial use cases will be for municipal scenarios such as buildings and parks, Transport data, Security, citizens' homes, and more (Smart Nation Sensor Platform, 2023). The Sensor platform is still under development during this interview.

During the following interview session with the Smart Nation team, we discussed the project's progress and how it envisions innovation and citizen inclusion to achieve more valuable results. As they explained, the smart city is seen as a complete ecosystem with multiple components that depend on the system in one way or another. Citizens are essential to the city, as they drive all the features

by usage, contribution, or economic impact. As the team analysed the situation, they realised how many public services needed optimisation. One of the problems was collecting citizens' details, which various government departments usually collected. By incorporating such a service with SingPass, the citizens were provided with the needed data. Furthermore, it provides a seamless interaction between citizens, government departments, and private companies. The healthcare sector, banks, and insurance companies currently gather information from citizens via the Singpass portal and MyInfo.

A primary focus area for the Smart Nation is to work on the actual city; this means improving infrastructure and urban landscape to achieve specific goals, such as the decarbonisation journey. Such work involves multiple service areas and physical infrastructure to become resource-efficient and to recycle resources. When the pandemic started at the beginning of 2020, it became even more essential to think about resilience and the circular economy. So, these strategies will form part of how Smart Nation further develops its initiatives. Regarding resilience, there are multiple areas that the city is working on, some related to citizens' skills improvement and others related to strategic plans and interventions in the economic or environmental areas. Some ways to improve the city are, for example, in the healthcare sector, where the Smart Nation is looking to collect data from communities and healthcare institutions to become more proactive in health interventions and improve citizens' daily lives. Some data collection can come from the public sector HealthHub app. Citizens sign up with their SingPass to access their health information and review results from hospitals or medical prescriptions.

Another example is the LumiHealth app, which interactively guides individuals to exercise and adjust their lifestyles to become healthier. This app collects information about individuals' exercise and motion patterns, heart rate and body measures (if entered), and responses to quizzes given in the app.

The Smart Nation teams work with the citizens by setting up innovation or engagement events to provide feedback. Volunteers join as Smart Nation Ambassadors, who engage in their local communities to support the individual citizens with the Smart Nation's new services or perform surveys to collect a community perception. As the team emphasised, the smart city project is about experimentation and getting feedback from the public. One example of citizen engagement that had a successful outcome was during the pandemic, when the migrant workers, who come from multiple language backgrounds, had to be engaged to give them accurate information about the pandemic and what sort of tests and precautions to take. The government had released an app that supported the four languages in Singapore, but this did not help the large group of migrant workers. They were lucky to get community support from citizens who could help train the workers to understand the App by identifying the problem.

Another discussion covered the COVID measures and the challenges the public sector faced in supporting citizens during the pandemic. The government set up the Safe-Distancing ambassadors, who kindly guided people to wear masks and keep their distance from each other. This was typically enforced in malls and food courts. When using TraceTogether app, the community centre was the centre for engagement, where people were invited to pick up the physical device and get help with the app. Here, many volunteers from the Smart Nation teams attended to support citizens while collecting feedback to further improve people's experiences by using the app and the checkpoint stations in malls and supermarkets.

The Smart Nation team referred to some examples for the TraceTogether app, including swiftly organising and rolling out the solution while ensuring the citizens could adapt to using it.

It was an empirical process in which the team realised that many senior citizens needed extra help. Many staff members from the Smart Nation team decided to volunteer and join the communities to guide the citizens with problems on how to use the app. This resulted in more citizens signing up and sharing their skills to teach others, and Smart Nation Ambassadors were created.

5.2 Results of survey data analysis

The survey was conducted online, and the questions were shared on social media like Facebook and LinkedIn. Other channels were via

personal and professional networks, where the questionnaires were further distributed. Finally, a manual face-to-face survey was conducted over 5 days. The total number of samples collected was 148 from residents of Singapore (Figure 10).

After the collection, the data was cleaned before analysing. The goal was to understand residents' views on the Tracetoegether app during the COVID period and their interest in smart city inclusion.

From the survey data, the majority of the participants represent the active workforce, aged from 25 to 64 years old, where 60.1% are between the ages of 35–54.

The survey data indicate that 49.3% believed that the TraceTogether app did help reduce the spread of COVID-19 (Figure 11). 65.5% of the respondents suggested that the government provided enough information about the TraceTogether app. And 64.2% of the respondents had a sense of participation and engagement

What is your age group

148 responses

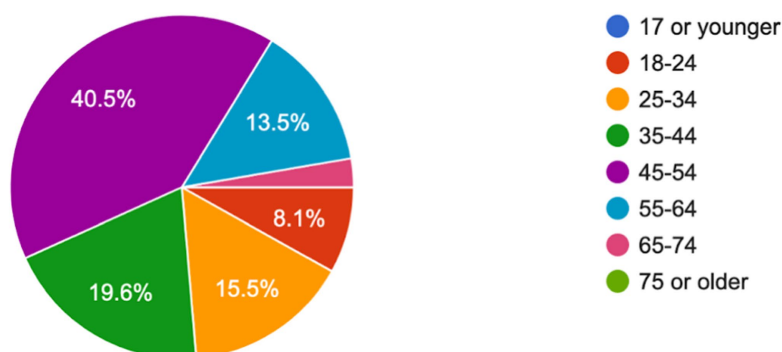


FIGURE 10
Survey age groups. Source: Authors survey data.

Did the TraceTogether app help reduce the spread of COVID-19?

148 responses

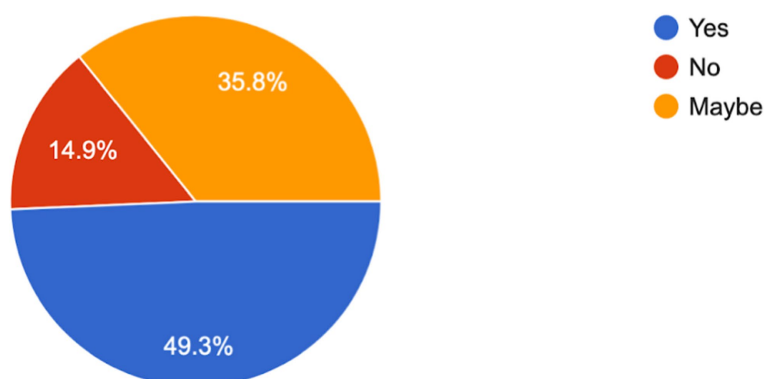


FIGURE 11
Survey: citizens' perception of TraceTogether. Source: Authors survey data.

in the fight against COVID spread (Figure 12). 70.9% felt the TraceTogether app contributed to a safer environment during the pandemic (Figure 13).

A few questions could give insight into the respondent's views on lifestyle, healthcare, transport, jobs, and education. But also, from the respondent's view on the involvement of citizens related to feedback, interviews, surveys, incentives, and city labs. By processing the survey data, it is possible to illustrate how the data correlate. In Figure 12, the data is shown in correlated data, and a value above 0.6 suggests higher interest from the respondents. For example, the factor of improved lifestyle related to healthcare, which comes from the questionnaire:

"What factors motivate you to participate in smart city projects?" where the respondent ranked from 1 to 5 (least to most) on the following factors: (a) Citizens' participation; (b) Public-private partnership; (c) Improved lifestyle; (d) Better healthcare, (e) Improved public transport, (f) Better education opportunities, (g) More job availability.

Likewise, from the correlation of the survey data in Figure 14, public transport scores high in healthcare, education, and lifestyle, 0.84, and 0.88. Where More jobs and education also score 0.79. These values suggest that these factors motivated the survey participants to participate in smart city projects.

Looking at the citizens' involvement in developing smart city projects, the following question was analysed:

"What are the most effective ways to involve citizens in developing smart city projects?" where the respondents ranked the following options from 1 to 5 (least to Most): (a) Survey, (b) City living labs, (c) Interviews, (d) Feedback and report solutions, (e) Inclusion with incentives.

From these data, the interviews and feedback score was highest at 0.72. The data suggested that the respondents have little interest in incentives related to smart city project involvement and very little interest in surveys.

The survey allowed the respondents to openly express their views on citizens' participation in smart city projects. In Figure 15, the word

Did the TraceTogether app enhance your sense of participation and engagement in the fight against COVID-19?

148 responses

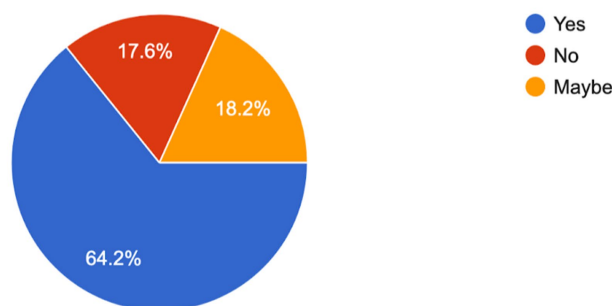


FIGURE 12

Survey respondents' sense of participation and engagement in the fight against COVID. Source: Authors survey data.

Do you think the TraceTogether app contributed to a safer environment for citizens during the pandemic?

148 responses

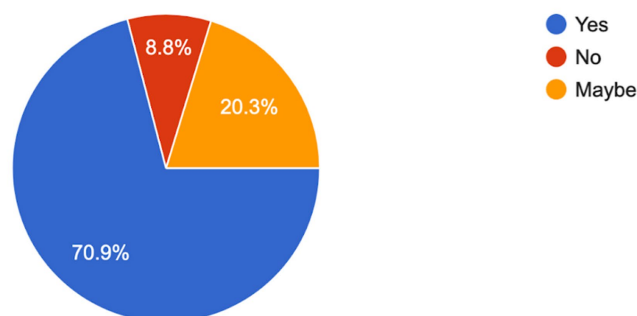
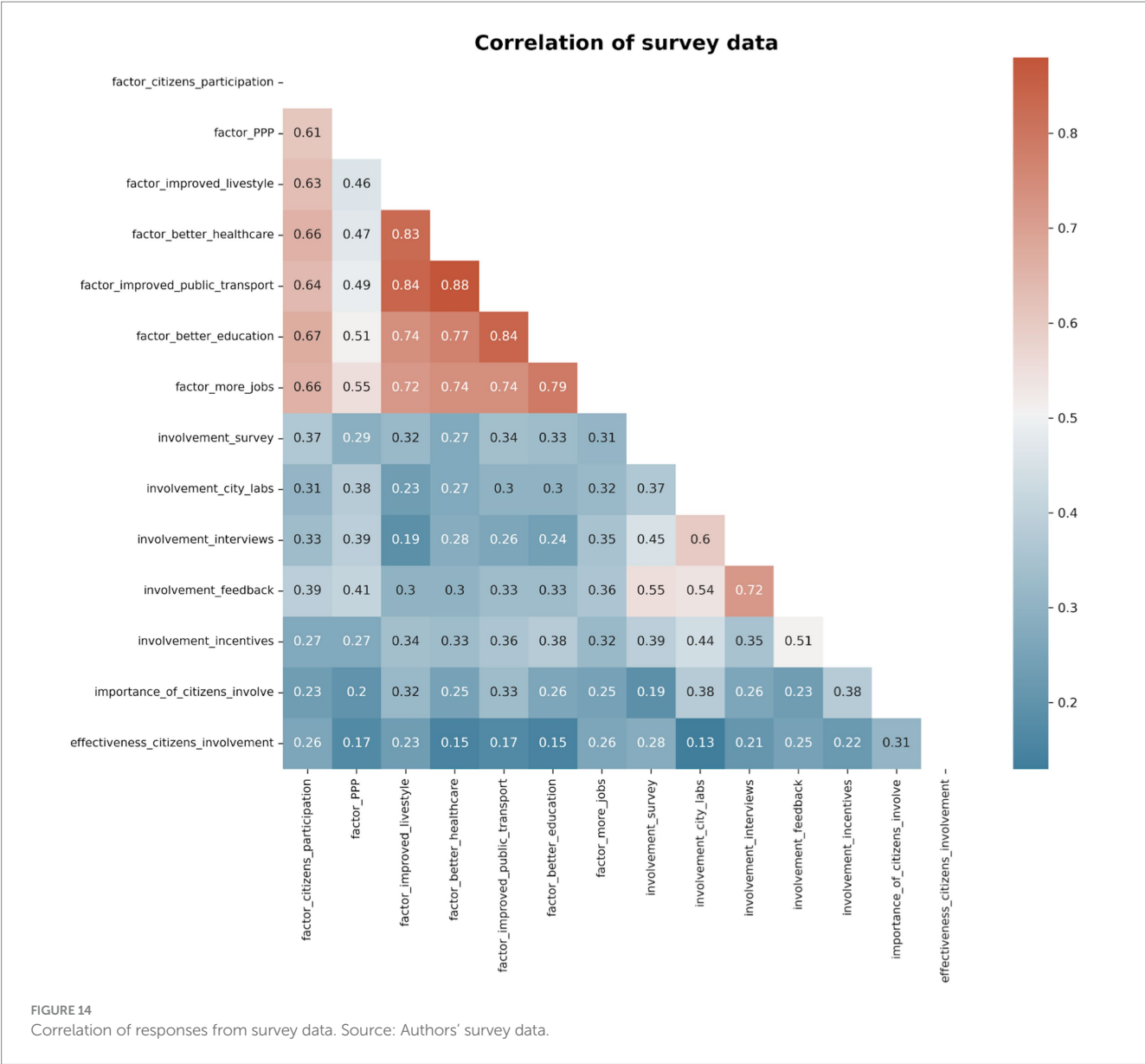


FIGURE 13

Survey respondents' perception of TraceTogether providing a safer environment during the pandemic. Source: Authors survey data.



cloud graph illustrates the most written words in the feedback survey, which contradicts the Incentive indicator from the survey. Moreover, there was a view on more awareness and focus on local needs when involving citizens—some more in-depth information and incentives when participating in projects.

5.2.1 Sentiment analysis

To understand the responder's feedback from the survey, it is possible to run a sentiment analysis from the phrases the responders submitted. The phrases were submitted from the following questions (Figure 16):

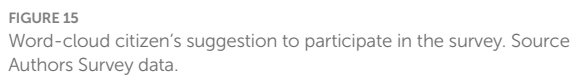
- 1 What factors influence citizens' willingness to participate in smart city projects?
- 2 What recommendations do you have for improving citizens' participation in smart city projects in Singapore?

The analysis was developed using a deep learning AI model named RoBERTA model (Tan et al., 2022). This model is trained to provide insight into sentiment analysis. And is more precise than the standard Vader model, available under the Python Natural Language Processing (NLP) library, Natural Language Tool Kit (NLTK) (Kavanagh et al., 2023).

By mapping the sentiment analysis up against the responder's ranked opinions, which are linked to the above questions (Figure 17):

- 1 How important is the government to involve citizens in developing smart city projects?
- 2 What factors motivate you to participate in smart city projects?

Using the Roberta sentiment analysis model, "What factors influence citizens' willingness to participate in smart city projects?" is



From the results, the sentiment analysis suggests that the positive response in the test also reflects the ranking of Most likely to agree. Even those who voted neutral tend to have positive feedback in the text response. Noticeably, the error margin is high when exploring the positive and negative sentiments, possibly due to the few words used in many responses.

Table 4 illustrates the most evident success factors from the findings, suggesting success with citizen inclusion in Singapore. As highlighted in the study, these factors significantly made Singapore's Smart Nation initiative successful. Citizen participation is pivotal in ensuring the effectiveness of urban innovations, with a strong

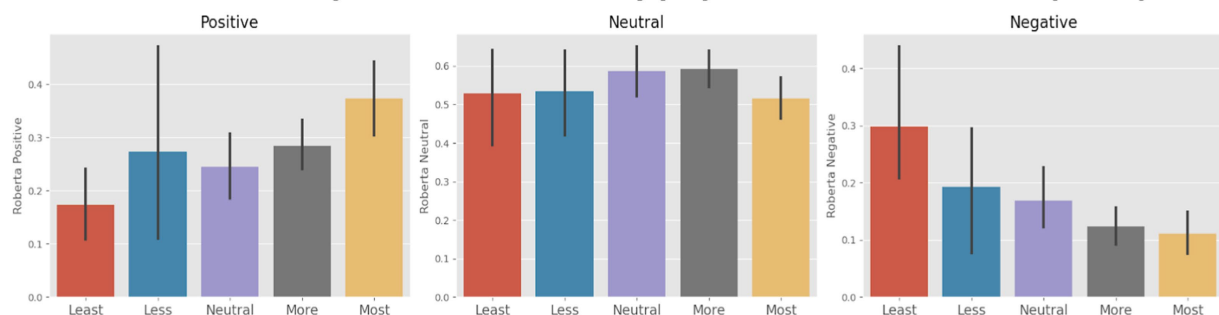


FIGURE 16
Sentiment analysis aligned with the success factor of citizens' participation. Source: Authors.



TABLE 4 Success factors and performance metrics.

Success factor	Reference	Description	Findings in study	Indicators and metrics
Citizen participation	Holum (2023) and Anthony (2023)	Involving citizens in co-designing and co-implementing smart services enhances inclusivity and the effectiveness of urban innovations.	Active citizen engagement in TraceTogether enhanced adoption and inclusivity.	Number of digital literacy programmes, percentage of marginalised groups with digital access.
Cross-functional government	Chew (2022), Ong (2021) and GovTech (2020b)	Coordinated government structures facilitate agile policy adaptation and crisis response.	Government collaboration ensured effective deployment of digital initiatives, particularly during COVID-19.	Time taken to implement solutions, effectiveness in reducing transmission rates.
Community engagement strategies	MOF Singapore (2018) and Smart Nation Engagement Programmes (2023)	Community-led initiatives and digital platforms foster collective responsibility and inclusion.	Community-driven engagement enhanced public trust and participation in smart governance.	Public approval ratings, privacy concerns addressed.
Digital literacy and inclusivity	PMO (2024c)	Initiatives like the Digital Inclusion Fund empower marginalised groups with essential digital tools and knowledge.	Digital literacy programmes enabled more equitable access to smart services and public health responses.	Ensured equitable technology access, improving adoption of smart city applications.
Supportive environment for innovation	Grossi and Trunova (2021) and Hämäläinen (2020)	Smart city policies must foster a dynamic ecosystem that supports technological advancements.	A well-supported tech ecosystem enabled the rapid deployment of solutions like TraceTogether.	Investment in digital infrastructure, adoption rate of smart applications.
Long-term engagement strategies	Leino and Puumala (2021)	Sustained citizen engagement is crucial beyond initial project launches to ensure continued participation and innovation.	Singapore's ongoing engagement strategies contributed to sustained adoption of smart services.	Retention rate of smart city initiatives, citizen feedback participation levels.
Comparative urban studies	Khan and Krishnan (2021) and Kaluarachchi (2022)	Learning from global smart city initiatives informs adaptable strategies for different urban contexts.	Comparative analyses highlight the need for transparent governance and multi-source data integration.	Rate of technology adaptation in various urban environments.
Public-private collaboration	Khan et al. (2020) and Sulistia and Nam (2022)	Partnerships between governments, businesses, and civil society enhance resource mobilisation and sustainability.	Public-private partnerships played a crucial role in the Smart Nation initiative's success.	Number of public-private partnerships, economic growth in smart sectors.

Source: Authors.

emphasis on inclusivity and engagement through various community initiatives. Cross-functional government coordination enabled timely and efficient responses, especially during the COVID-19 crisis, highlighting the value of collaboration across different sectors.

Community engagement strategies and support for digital literacy ensured that all citizens, including marginalised groups, had equitable access to technological tools and opportunities to contribute to smart city projects.

Despite its successes, Singapore's strategy also revealed critical gaps compared to international best practices (Table 5). Lessons drawn from other smart cities emphasise key elements that could further enhance citizen participation and trust:

Multi-Source Data Integration Enhances Accuracy

- South Korea utilised CCTV, GPS, and transaction data for COVID-19 tracking, enhancing efficiency (Esposito et al., 2021).

- Singapore's reliance on Bluetooth-based tracking limited data precision.

Privacy and Trust Influence Public Participation

- Public trust declined when Singapore revealed that TraceTogether data was used for law enforcement (Chow et al., 2023).
- Taiwan and Germany ensured transparency, fostering confidence in data-sharing mechanisms.

Balancing Adoption and Voluntariness

- The UK and Germany's voluntary models faced low adoption rates, impacting effectiveness.
- Singapore's regulatory mandates ensured high participation but eroded trust over time.

TABLE 5 Gaps in Singapore's strategy vs. global best practices.

City/Country	COVID-19 measure	Success rate	Citizen engagement	Reference
Singapore	TraceTogether (Bluetooth-based DCT)	Moderate (Reduced tracing time by 34.9%)	Moderate (92% awareness but only 49% adoption)	Chow et al. (2023)
South Korea	Multi-source data tracking (GPS, CCTV, bank transactions)	High	High (Transparent communication)	Sonn et al. (2020)
Germany	Decentralised DCT (Apple-Google framework)	Low (Voluntary adoption)	High (Strong data privacy policies)	Esposito et al. (2021)
Taiwan	QR-code based tracking and manual tracing integration	High	High (Public trust in government-led efforts)	Esposito et al. (2021)
United Kingdom	United Kingdom	Moderate	Low (Public distrust in government data handling)	Esposito et al. (2021)

Scalability and Flexible Engagement

- Citizen engagement in Singapore was predominantly government-driven, limiting grassroots innovation.
- Cities like Barcelona and Copenhagen successfully leveraged participatory budgeting and crowdsourcing to involve the public in smart city planning ([Kaluvarachchi, 2022](#)).

This inclusivity, supported by initiatives like the Digital Inclusion Fund, contributed to the resilience and adaptability of the smart city framework during challenging periods. Furthermore, a supportive environment for innovation facilitated technological adoption, which was vital for the success of projects like the TraceTogether app.

The study also highlighted the importance of sustaining long-term citizen engagement and the role of comparative urban studies in crafting successful strategies across diverse urban contexts. Smart city strategies should balance privacy, transparency, citizen trust, and multi-source data integration to ensure both adoption and inclusivity. Lessons from South Korea, Taiwan, and European cities underscore the significance of transparent governance and decentralised citizen participation models.

6 Conclusion

The TraceTogether app played a crucial role in Singapore's COVID-19 response, effectively supporting the government's broader public health strategy. As a digital contact tracing tool, its successful implementation reduced strain on the healthcare system, even during spikes in COVID-19 cases. By enabling rapid identification and isolation of potential infection clusters, TraceTogether helped mitigate uncontrolled virus spread, ultimately protecting hospital capacity and preventing overwhelming demand for healthcare services.

While Singapore did introduce financial support schemes for businesses, the economic impact was uneven. The most significant disruptions were felt in the Food & Beverage (F&B) and entertainment sectors, which relied heavily on in-person visits. Despite government assistance, businesses in these sectors faced substantial challenges as restrictions and reduced foot traffic impacted their revenue.

Singapore's success with TraceTogether can be attributed to a few contextual factors:

Policy and Legal Compliance

- Unlike many other countries where digital contact tracing faced public resistance, Singapore's population generally accepts and adheres to government policies and legal mandates. This cultural and governance dynamic allowed for high adoption rates and effective enforcement of public health measures.

City-State Advantage

- As a small, densely populated city-state, Singapore could implement and enforce contact tracing measures with greater efficiency compared to larger nations such as Thailand or Spain, where geographical spread and multiple jurisdictions would have made centralised digital tracing significantly more complex.

Ultimately, the TraceTogether app, alongside decisive government policies and strong public cooperation, demonstrated how a well-executed digital innovation could contribute to effective pandemic management. Singapore's case highlights the importance of contextual governance, digital trust, and infrastructure readiness in determining the success of smart city solutions in crisis response ([Chew, 2022](#); [Ong, 2021](#); [GovTech, 2020b](#)). These elements highlight the importance of creating a supportive environment for technology adoption and community involvement, which are pivotal for the success of smart city projects ([Grossi and Trunova, 2021](#); [Hämäläinen, 2020](#)).

Citizen participation emerged as a key success factor, with data showing that involving citizens in the design and implementation of services increases social inclusion and enhances the overall effectiveness of urban innovations ([Holum, 2023](#); [Anthony, 2023](#)). The Singapore government's active engagement strategies—including community-based initiatives and technology platforms—have fostered a sense of collective responsibility among citizens, particularly during times of crisis ([MOF Singapore, 2018](#); [Smart Nation Engagement Programmes, 2023](#)). Additionally, Singapore's emphasis on digital literacy and support for marginalised communities through programmes like the Digital Inclusion Fund further demonstrate how inclusivity contributes to the resilience and success of smart city projects ([PMO, 2024c](#)).

Findings from global best practices show significant overlaps with Singapore's success factors. For example, multi-source data integration has been a key determinant in the effectiveness of smart

city applications, as seen in South Korea's use of CCTV, GPS, and transaction data for enhanced COVID-19 tracking (Esposito et al., 2021). In contrast, while effective, Singapore's reliance on Bluetooth-based tracking was limited in precision. Similarly, transparency and trust in data privacy have influenced public participation across different smart city contexts. Taiwan and Germany, for instance, ensured transparency in data-sharing mechanisms, fostering greater citizen confidence (Chow et al., 2023).

Furthermore, Singapore's strategic use of regulatory mandates ensured high adoption rates for TraceTogether. However, this came at the cost of long-term trust when it was revealed that law enforcement had access to collected data (Chow et al., 2023). In contrast, voluntary models in the UK and Germany faced low adoption rates, limiting their effectiveness. These comparative insights highlight the need to balance adoption strategies with transparent communication to maintain public trust in smart city initiatives.

Beyond crisis response, findings suggest that smart city strategies must incorporate flexible engagement approaches that encourage bottom-up innovation. While Singapore's government-driven approach was effective, cities such as Barcelona and Copenhagen have successfully leveraged participatory budgeting and crowdsourcing mechanisms to involve the public in smart city planning (Kaluvarachchi, 2022). These alternative approaches highlight the benefits of a decentralised model that gives citizens a more active role in shaping their urban environments.

To advance citizen inclusion in future smart city projects, a few key areas of focus emerge:

Sustaining Citizen Engagement Beyond Initial Project Launches

- Long-term engagement strategies must be developed to maintain citizen interest and involvement in smart city projects. Research suggests consistent participation is essential to sustaining innovation and responsiveness in urban initiatives (Leino and Puumala, 2021).

Comparative Urban Studies for Adaptive Strategies

- Future studies should explore how different cultural, economic, and social contexts influence the success of citizen participation in smart cities. Adapting strategies from global case studies can inform more inclusive and locally appropriate urban innovation frameworks (Khan and Krishnan, 2021; Kaluvarachchi, 2022).

Balancing Transparency, Privacy, and Public Trust

- Smart city initiatives must ensure transparency in data usage and privacy policies to maintain public trust. Establishing clear guidelines and oversight mechanisms will foster citizen confidence in digital governance (Chow et al., 2023).

Decentralising Innovation and Encouraging Grassroots Involvement

- While Singapore's top-down approach was efficient, future projects could incorporate decentralised participation models to encourage bottom-up innovation. This could include open data platforms, digital participatory forums, and collaborative urban labs to give citizens more agency in shaping smart city solutions (Kaluvarachchi, 2022).

However, while Singapore has been successful in many aspects, the findings also suggest areas for further research. Future studies could investigate the impact of long-term citizen engagement strategies on the sustainability of smart city projects, mainly focusing on maintaining interest and involvement beyond initial project launches (Leino and Puumala, 2021). Moreover, exploring comparative case studies in different urban environments could provide a broader understanding of how cultural, economic, and social contexts influence the success of citizen participation in smart cities (Khan and Krishnan, 2021; Kaluvarachchi, 2022).

As cities worldwide continue integrating smart technologies into their governance structures, adopting adaptable, transparent, and participatory approaches will ensure adoption and inclusivity.

Data availability statement

The original contributions presented in the study are publicly available. This data can be found here: <https://www.kaggle.com/datasets/motethansen/citizens-survey>.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants OR patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

MMH: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. BD: Supervision, Conceptualization, Methodology, Formal analysis, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

References

- Aghaloo, K., and Sharifi, A. (2024). Integrated spatial prioritization of urban nature-based solutions for climate adaptation, mitigation, and justice. *Int. J. Sustain. Dev. World Ecol.* 32, 224–241. doi: 10.1080/13504509.2024.2424988
- Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., and Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities* 60, 234–245. doi: 10.1016/j.cities.2016.09.009
- Alamoudi, A. K., Abidoye, R. B., and Lam, T. Y. M. (2022). The impact of stakeholders' management measures on citizens' participation level in implementing smart sustainable cities. *Sustain. For.* 14:16617. doi: 10.3390/su142416617
- Alanzi, T. (2021). A review of Mobile applications available in the app and Google play stores used during the COVID-19 outbreak. *J. Multidiscip. Healthc.* 14, 45–57. doi: 10.2147/JMDH.S285014
- Alarabiat, A. (2016). Electronic participation through social media: citizens' adoption factors at local government level. In Proceedings of the 9th international conference on theory and practice of electronic governance. ICEGOV 15–16, 424–27. New York, NY, USA: Association for Computing Machinery.
- Albino, V., Berardi, U., and Dangelico, R. M. (2015). Smart cities: definitions, dimensions, performance, and initiatives. *J. Urban Technol.* 22, 3–21. doi: 10.1080/10630732.2014.942092
- Anthony, B. (2023). The role of community engagement in urban innovation towards the co-creation of smart sustainable cities. *J. Knowl. Econ.* 15, 1592–1624. doi: 10.1007/s13132-023-01176-1
- Arnstein, S. R. (1969). A ladder of citizen participation. *J. Am. Inst. Plann.* 35, 216–224. doi: 10.1080/01944366908977225
- Athanassiou, E. (2023). Participation as a global urban strategy towards resilience: a case of “benevolent urbanism”. *J. Public Space* 8, 45–60. doi: 10.32891/jps.v8i3.1199
- Bastos, D., Costa, N., Rocha, N. P., Fernández-Caballero, A., and Pereira, A. (2024). A comprehensive survey on the societal aspects of smart cities. *Appl. Sci.* 14:7823. doi: 10.3390/app14177823
- Bay, J. (2022). Safer together: TraceTogether and the future of digital contact tracing. *XRDS: Crossroads ACM Mag. Students* 28, 48–55. doi: 10.1145/3522695
- Boorsma, B. (2018). (3) the skills and competencies required for smarter communities - and why we are not ready | LinkedIn. Available at: <https://www.linkedin.com/pulse/skills-competencies-required-smarter-communities-why-bas-boorsma/> (Accessed April 4, 2018).
- Bremser, C., Piller, G., and Helfert, M. (2019). “Technology adoption in smart city initiatives: starting points and influence factors”: in Proceedings of the 8th international conference on smart cities and green ICT systems, 70–79. Heraklion, Crete, Greece: SCITEPRESS - Science and Technology Publications.
- Bris, A., Cabolis, C., Lanvin, B., Caballero, J., Hediger, M., Jobin, C., et al. (2021). Smart city index 2021. IMD. Available at: <https://www.imd.org/smart-city-observatory/home/> (Accessed February 16, 2023).
- Calder, K. E. (2016). Singapore: Smart city smart state. Washington, D.C.: Brookings Institution Press.
- Cardullo, P., and Kitchin, R. (2019). Smart urbanism and smart citizenship: the neoliberal logic of “citizen-focused” smart cities in Europe. *Environ. Plan. C Polit. Space* 37, 813–830. doi: 10.1177/0263774X18806508
- Carvajal Bermúdez, J. C., and König, R. (2021). The role of technologies and citizen organizations in decentralized forms of participation. A case study about residential streets in Vienna. *Technol. Soc.* 66:101604. doi: 10.1016/j.techsoc.2021.101604
- Chang, F., and Das, D. (2020). Smart nation Singapore: developing policies for a citizen-oriented smart city initiative. Singapore: Springer. doi: 10.1007/978-981-15-3738-7_18
- Chew, H. M. (2022). TraceTogether and SafeEntry no longer needed for most venues from Apr 26. CNA. Available at: <https://www.channelnewsasia.com/singapore/covid19-tracetoegether-safeentry-step-down-2641231> (Accessed April 22, 2022).
- Chow, B. W. K., Lim, Y. D., Poh, R. C. H., Ko, A., Hong, G. H., Zou, S. W. L., et al. (2023). Use of a digital contact tracing system in Singapore to mitigate COVID-19 spread. *BMC Public Health* 23:2253. doi: 10.1186/s12889-023-17150-0
- Chua, H. S. (2021). Visualising the COVID-19 spread in Singapore using tableau. Medium (blog). Available at: <https://huishun.medium.com/visualising-the-covid-19-spread-in-singapore-using-tableau-2b4c8ea92273> (Accessed June 8, 2021).
- Cortés-Cediel, M. E., Cantador, I., and Bolívar, M. P. R. (2021). Analyzing citizen participation and engagement in European smart cities.
- Costales, E. (2022). Identifying sources of innovation: building a conceptual framework of the smart city through a social innovation perspective. *Cities* 120:103459. doi: 10.1016/j.cities.2021.103459
- Esposito, D., Dipierro, G., Sonnessa, A., Santoro, S., Pascasio, S., and Pluchinotta, I. (2021). Data-driven epidemic intelligence strategies based on digital proximity tracing technologies in the fight against COVID-19 in cities. *Sustain. For.* 13:644. doi: 10.3390/su13020644
- Fabré, B. F. G., and Bogoni, A. (2023). Privacy and security concerns in the smart city. *Smart Cities* 6, 586–613. doi: 10.3390/smartcities6010027
- Fowler, A. (2021). Singapore's GovTech donates OpenTrace to Linux foundation public health's herald project. Herald Project. Available at: <https://heraldprox.io/blog/opentrace-donation> (Accessed August 24, 2021).
- Geekyanage, D., Fernando, T., and Keraminiyage, K. (2021). Mapping participatory methods in the urban development process: a systematic review and case-based evidence analysis. *Sustain. For.* 13:8992. doi: 10.3390/su13168992
- GovTech. (2020a). Improving TraceTogether through community engagement. Available at: <https://www.tech.gov.sg/media/technews/2020-07-06-tracetoegether-token-teardown> (Accessed July 6, 2020).
- GovTech. (2020b). TraceTogether - behind the scenes look at its development process. Available at: <https://www.tech.gov.sg/media/technews/tracetoegether-behind-the-scenes-look-at-its-development-process> (Accessed March 25, 2020).
- GovTech. (2023). TraceTogether – community-driven contact tracing. Singapore Government Developer Portal. Available online at: <https://www.developer.tech.gov.sg/products/categories/digital-solutions-to-address-covid-19/tracetoegether/overview.html> (Accessed January 25, 2023).
- Grossi, G., and Trunova, O. (2021). Are UN SDGs useful for capturing multiple values of smart city? *Cities* 114:103193. doi: 10.1016/j.cities.2021.103193
- Hämäläinen, M. (2020). A framework for a smart city design: digital transformation in the Helsinki smart city. In Entrepreneurship and the community: a multidisciplinary perspective on creativity, social challenges, and business, edited by Vanessa Ratten, 63–86. Cham: Springer International Publishing.
- Henderson, J. C. (2012). Planning for success: Singapore, the model city-state? *J. Int. Affairs* 65, 69–83.
- Holum, M. (2023). Citizen participation: linking government efforts, actual participation, and trust in local politicians. *Int. J. Public Adm.* 46, 915–925. doi: 10.1080/01900692.2022.2048667
- Huang, S. (2001). Planning for a tropical city of excellence: urban development challenges for Singapore in the 21st century. *Built Environ.* 27, 112–128.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsc.2025.1552449/full#supplementary-material>

- Huang, Z., Guo, H., Lim, H. Y. F., and Chow, A. (2021). Awareness, acceptance, and adoption of the national digital contact tracing tool post COVID-19 lockdown among visitors to a public hospital in Singapore. *Clin. Microbiol. Infect.* 27, 1046–1048. doi: 10.1016/j.cmi.2021.01.007
- Hui, C. X., Dan, G., Alamri, S., and Toghræ, D. (2023). Greening smart cities: an investigation of the integration of urban natural resources and smart city technologies for promoting environmental sustainability. *Sustain. Cities Soc.* 99:104985. doi: 10.1016/j.scs.2023.104985
- Jiménez-Caldera, J., Durango-Severiche, G. Y., Pérez-Arévalo, R., Serrano-Montes, J. L., Rodrigo-Comino, J., and Caballero-Calvo, A. (2024). Methodological proposal for the inclusion of citizen participation in the management and planning of urban public spaces. *Cities* 150:105008. doi: 10.1016/j.cities.2024.105008
- Kaluarachchi, Y. (2022). Implementing data-driven smart city applications for future cities. *Smart Cities* 5, 455–474. doi: 10.3390/smartcities5020025
- Kavanagh, J., Greenhow, K., and Jordanous, A. (2023). Assessing the effects of lemmatisation and spell checking on sentiment analysis of online reviews. 2023 IEEE 17th international conference on semantic computing (ICSC), February, 235–238.
- Khan, A., and Krishnan, S. (2021). Citizen engagement in co-creation of e-government services: a process theory view from a meta-synthesis approach. *Internet Res.* 31, 1318–1375. doi: 10.1108/INTR-03-2020-0116
- Khan, H. H., Malik, M. N., Zafar, R., Goni, F. A., Chofreh, A. G., Klemeš, J. J., et al. (2020). Challenges for sustainable smart city development: a conceptual framework. *Sustain. Dev.* 28, 1507–1518. doi: 10.1002/sd.2090
- Kolotouchkina, O., González, L. R., and Belabas, W. (2024). Smart cities, digital inequalities, and the challenge of inclusion. *Smart Cities* 7, 3355–3370. doi: 10.3390/smartcities7060130
- Kong, J., Bocquet, C., and Bauer, G. K. (2021). Innovative data for urban planning opportunities and challenges associated with public private data partnerships. Available at: <https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/07/Innovative-Data-for-Urban-Planning-Opportunities-and-Challenges-Associated-with-Public-Private-Data-Partnerships-SPREADS.pdf> (Accessed March 24, 2023).
- KPMG. (2021). Singapore tops 2021 ranking for leading technology innovation hubs: KPMG survey - KPMG Singapore. KPMG. Available at: <https://kpmg.com/sg/en/home/media/press-releases/2021/07/singapore-tops-2021-ranking-for-leading-technology-innovation-hubs-kpmg-survey.html> (Accessed July 16, 2021).
- Kumar, D. (2024). Actual practices of citizen participation in smart cities. *Smart Cities Reg. Dev. (SCRD)* J. 8, 19–30. doi: 10.25019/4c05yr24
- Leino, H., and Puumala, E. (2021). What can co-creation do for the citizens? Applying co-creation for the promotion of participation in cities. *Environ. Plan. C Polit. Space* 39, 781–799. doi: 10.1177/2399654420957377
- Lim, S., Malek, J. A., Hussain, M. Y., and Tahir, Z. (2018). Citizen participation in building citizen-centric smart cities. *Malay. J. Soc. Space* 14, 42–53. doi: 10.17576/geo-2018-1404-04
- Limna, P. (2023). A review of transformation and digital literacy for the sustainable development in the greater Mekong subregion – Working paper.
- McPhearson, T., Kabisch, N., and Frantzeskaki, N. (2023). Chapter 1: nature-based solutions for sustainable, resilient, and equitable cities. Available at: <https://www.elgaronline.com/edcollchap-0a/book/9781800376762/book-part-9781800376762-8.xml> (Accessed December 15, 2023).
- Meijer, A., and Bolívar, M. P. R. (2016). Governing the smart city: a review of the literature on smart urban governance. *Int. Rev. Adm. Sci.* 82, 392–408. doi: 10.1177/0020852314564308
- Michels, A., and De Graaf, L. (2017). Examining citizen participation: local participatory policymaking and democracy revisited. *Local Gov. Stud.* 43, 875–881. doi: 10.1080/03003930.2017.1365712
- MOF Singapore, ed. (2018). A better future through partnerships and good governance. Available at: https://www.mof.gov.sg/docs/default-source/default-document-library/spor-2018/pdf/SPOR_2018_Chapter_5.pdf
- Nam, T., and Pardo, T. A. (2011). 'Conceptualizing smart city with dimensions of technology, people, and institutions'. In Proceedings of the 12th annual international digital government research conference: digital government innovation in challenging times, 282–291. New York, NY, USA: Association for Computing Machinery.
- Network Training Center (NTC). (2022). Citizen empowerment with Traffy Fondue by Wasan Pattara-Atikom. Available at: <https://www.youtube.com/watch?v=pdAv8kTNH8M> (Accessed June 1, 2023).
- Nielsen, B. Fl., Baer, D., Gohari, S., and Junker, E. (2019). The potential of design thinking for tackling the “wicked problems” of the smart city. CORP – Competence Center of Urban and Regional Planning. Available at: <https://sintef.brage.unit.no/sintef-xmlui/handle/11250/2625493> (Accessed July 15, 2020).
- Oliveiro, V. (2021). Contact tracing tech across the data life cycle. CSC. Available online at: <https://www.csc.gov.sg/articles/contact-tracing-tech-across-the-data-life-cycle> (Accessed June 29, 2021).
- Ong, J. (2021). S'pore takes top spot in ranking of smart city Govts, praised for “Sterling” Covid-19 response, digital initiatives. Today. Available at: <https://www.todayonline.com/singapore/spore-takes-top-spot-ranking-smart-city-govts-praised-sterling-covid-19-response-digital> (Accessed March 31, 2021).
- Ong, J. (2022). The straits times releases in this together, a behind-the-scenes look at Singapore's Covid-19 Story. The Straits Times. Available at: <https://www.straitstimes.com/singapore/health/the-straits-times-releases-in-this-together-a-behind-the-scenes-look-at-singapores-covid-19-story> (January 20, 2022).
- Ooi, G. L., and Phua, K. H. (2009). SARS in Singapore—challenges of a global health threat to local institutions. *Nat. Hazards (Dordrecht, Netherlands)* 48:317. doi: 10.1007/s11069-007-9194-2
- PMO. (2024a). Digital economy. Available at: <https://www.smartnation.gov.sg/about-smart-nation/digital-economy/> (Accessed April 23, 2024).
- PMO. (2024b). Digital government. Available at: <https://www.smartnation.gov.sg/about-smart-nation/digital-government/> (Accessed April 23, 2024).
- PMO. (2024c). Digital society. Available at: <https://www.smartnation.gov.sg/about-smart-nation/digital-society/> (Accessed April 23, 2024).
- PMO. (2024d). OneService App. Available at: <https://www.smartnation.gov.sg/initiatives/urban-living/oneservice-app/> (Accessed April 23, 2024).
- PMO. (2024e). Our strategic national projects. Available at: <https://www.smartnation.gov.sg/initiatives/strategic-national-projects/> (Accessed April 17, 2024).
- PMO. (2024f). Smart nation sensor platform. Available at: <https://www.smartnation.gov.sg/initiatives/strategic-national-projects/smart-nation-sensor-platform/> (Accessed April 17, 2024).
- Reichental, J. (2020). Smart cities for dummies. Hoboken, New Jersey: John Wiley & Sons, Inc.
- Simonofski, A., Asensio, E. S., and Wautelet, Y. (2019). “Chapter 4 - citizen participation in the design of smart cities: methods and management framework” in Smart cities: issues and challenges. eds. A. Visvizi and M. D. Lytras (Cambridge, US: Elsevier), 47–62.
- Simonofski, A., Hertoghe, E., Steegmans, M., Snoeck, M., and Wautelet, Y. (2021). Engaging citizens in the smart city through participation platforms: a framework for public servants and developers. *Comput. Hum. Behav.* 124:106901. doi: 10.1016/j.chb.2021.106901
- Simonofski, A., Van Den Storme, S., and Meers, H. (2020). “Towards a holistic evaluation of citizen participation in smart cities” in The 21st annual international conference on digital government research (New York, NY, USA: Association for Computing Machinery), 82–89.
- Singapore Computer Society. (2020). Singapore smart nation initiatives and possible opportunities - Singapore Computer Society. Singapore smart nation initiatives and possible opportunities. Available online at: <https://www.scs.org.sg/articles/smart-nation-singapore> (Accessed March 18, 2023).
- Singpass. (2023). Available online at: <https://www.tech.gov.sg/products-and-services/singpass/> (Accessed July 4, 2023).
- Sipahi, E. B., and Saayi, Z. (2024). The world's first “smart nation” vision: the case of Singapore. *Smart Cities Reg. Dev. (SCRD)* J. 8, 41–58. doi: 10.25019/dvm98x09
- SLA, Singapore Land Authority. (2024). The most detailed and comprehensive map of Singapore. The most detailed and comprehensive map of Singapore. Available online at: <https://www.onemap.gov.sg/home/> (Accessed November 28, 2024).
- Smart Nation. (2023). Apps for you. Smart Nation. Available online at: <https://www.smartnation.gov.sg/community/apps-for-you/> (Accessed 23 March 2023).
- Smart Nation Ambassadors. (2023). Available online at: <https://www.smartnation.gov.sg/community/smart-nation-ambassadors/> (Accessed February 2023).
- Smart Nation Engagement Programmes. (2023). Available online at: <https://www.smartnation.gov.sg/community/Contribute-to-Smart-Nation> (Accessed 24 March 2023).
- Smart Nation Sensor Platform. (2023). Available online at: <https://www.smartnation.gov.sg/initiatives/strategic-national-projects/smart-nation-sensor-platform/>
- Smart Nation Singapore. (2023). Pillars of a smart nation. Available online at: <https://www.smartnation.gov.sg/about-smart-nation/pillars-of-smart-nation>.
- Sokolov, A., Veselitskaya, N., Carabias, V., and Yildirim, O. (2019). Scenario-based identification of key factors for smart cities development policies. *Technol. Forecast. Soc. Chang.* 148:119729. doi: 10.1016/j.techfore.2019.119729
- Sonn, J. W., Kang, M., and Choi, Y. (2020). Smart city technologies for pandemic control without lockdown. *Int. J. Urban Sci.* 24, 149–151. doi: 10.1080/12265934.2020.1764207
- Stevens, T., and Dunnage, N. (2020). An architecture for secure COVID-19 contact tracing. Cloudera Blog. Available online at: <https://blog.cloudera.com/an-architecture-for-secure-covid-19-contact-tracing/> (Accessed April 17, 2020).
- Sulistia, E., and Nam, K. W. (2022). Public, private, people partnership framework for developing Indonesian smart city infrastructure. *Int. J. Environ. Sustain. Soc. Sci.* 3, 267–275. doi: 10.38142/ijess.v3i2.211
- Tan, G. K. S., and Lim, S. S. (2022). ‘Communicative strategies for building public confidence in data governance: analyzing singapore's COVID-19 contact-tracing

initiatives'. *Big Data & Society*. 9:20539517221104086. doi: 10.1177/20539517221104086

Tan, K. L., Lee, C. P., Anbananthen, K. S. M., and Lim, K. M. (2022). RoBERTa-LSTM: a hybrid model for sentiment analysis with transformer and recurrent neural network. *IEEE Access* 10, 21517–21525. doi: 10.1109/ACCESS.2022.3152828

Tan, S. The Straits Times Covid-19 Team (2022). In this together: Singapore's Covid-19 story. Singapore: Straits Times Press.

Tappert, S., Mehan, A., Tuominen, P., and Varga, Z. (2024). Citizen participation, digital agency, and urban development | editorial | urban planning January. Available online at: <https://www.cogitatiopress.com/urbanplanning/article/view/7810> (Accessed February 23, 2025).

TraceTogether. (2021). TraceTogether. Available online at: <https://www.tracetgether.gov.sg> (Accessed March 11, 2021).

United Nations. (2018). 68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of economic and social affairs. Available online at: <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html> (Accessed May 16, 2018).

United Nations. (2021). Goal 11 | Department of Economic and Social Affairs. Available online at: <https://sdgs.un.org/goals/goal11> (Accessed March 19, 2023).

Van Der Graaf, S., and Ballon, P. (2019). Navigating platform urbanism. *Technol. Forecast. Soc. Change* 142, 364–372. doi: 10.1016/j.techfore.2018.07.027

Wolff, A., Gooch, D., Caverio, J., Rashid, U., and Kortuem, G. (2018). Removing barriers for citizen participation to urban innovation.

Woods, O., Bunnell, T., and Kong, L. (2024). Insourcing the smart city: assembling an ideo-technical ecosystem of talent, skills, and civic-mindedness in Singapore. *Urban Geogr.* 45, 735–754. doi: 10.1080/02723638.2023.2233353

Yang, H., Chen, H., Pan, T., Lin, Y., Zhang, Y., and Chen, H. (2022). Studies on the digital inclusion among older adults and the quality of life-a Nanjing example in China. *Front. Public Health* 10:811959. doi: 10.3389/fpubh.2022.811959

Yuen, T. (2021). More than 4.2m people using TraceTogether, token distribution to resume soon: Lawrence Wong. The Straits Times. Available online at: <https://www.straitstimes.com/singapore/politics/parliament-more-than-42m-people-using-tracetgether-token-distribution-to-resume> (Accessed March 26, 2023).