Technology, innovation and governance

Building climate-resilient cities and addressing demographics crises

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Abstract

This article examines three Japanese smart cities—Toyama City, Fujisawa Sustainable Smart Town, and Tsuchiyu Onsen—to identify how technologies, policies, and practices contribute to climate resilience and address demographic challenges. Our findings show that smart cities require a balanced approach between technology adoption, innovation, and democratic governance rather than a one-size-fits-all solution. We emphasize that stakeholder management and transparent public engagement are essential for maximizing technological effectiveness. By fostering public understanding, running drills, and feedback mechanisms, smart city initiatives can ensure proper technology utilization, generate data for assessing governmental goals, and guide future technological and policy needs.

Introduction

With climate change damaging city infrastructure and straining budgets, governments and communities will look for ways to build more resilient cities cost-effectively. Cities worldwide, including Japan, are turning to technologies such as smart grids, mass transit, renewable energy, artificial intelligence (AI), and automation to build sustainable cities while addressing demographic and economic challenges. Equally important as identifying and implementing new technology, however, are sound governance and support for innovation among the public-private-academic sectors. In recent years, urban design philosophies, city development policies, and democratic government-citizen relations have fallen under the umbrella term of "smart cities."

This article examines the cases of Toyama City, Fujisawa Sustainable Smart Town (SST), and Tsuchiyu Onsen to identify technology, best practices, areas of opportunity, and challenges that must be overcome in smart city development. We find that even within a single country, a one-size-fits-all approach does not work, and climate-resilient infrastructure must be tailored to the strengths and weaknesses of each community. Moreover, we argue that consistent stakeholder management and transparent engagement with the public will allow the government to best leverage the technologies it seeks to implement. Gaining public understanding, running drills, and maintaining robust feedback loops will ensure that smart city technologies will be used as intended, provide valuable data to determine if the government is meeting its desired benchmarks, and provide insights on what technologies and policies are needed for long-term sustainability.

Smart cities in theory

There are numerous definitions of the concept of "smart city," with many developed by international organizations. Philip Bane, of the Smart Cities Council, identifies three core components of a smart city: 1) "'Cities' are any human community of any size and 'smart' can be technology, people and process," 2) "At the core of smart cities are people, and the human-centered needs of livability, workability, and sustainability are at the core of every smart city program or project," and 3) "Information and communication technology are core to technology development" (Bane, 2022). The European Commission defines a smart city as "a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of inhabitants and business" (European Commission, n.d.). The European Commission emphasizes that smart cities go beyond better resource management and less emissions through digital technology and highlights the importance of smarter urban transport networks, more interaction between the public and city administration, and meeting the needs of an aging population, among other urban planning advancements. Although intuitively, these smart technologies contribute to more climate-resistant infrastructure and can address climate change, they are not solely focused on environmental issues. More importantly, smart technologies can negatively impact the environment, as AI and battery technolo-

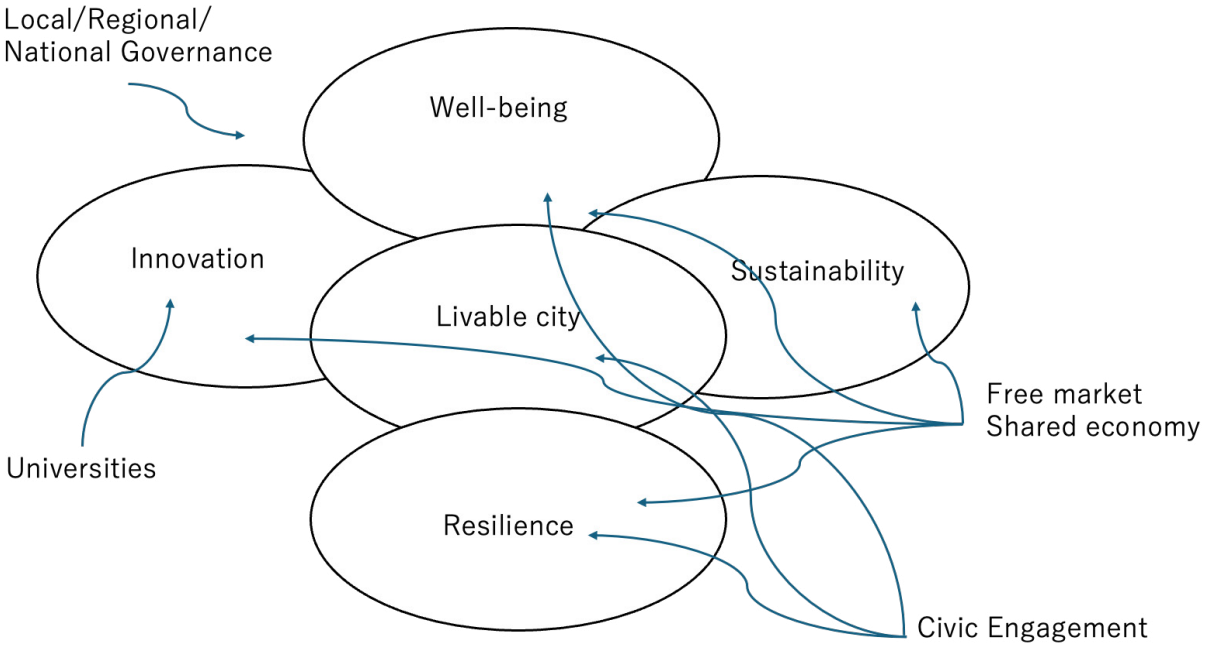

Figure 1. Core components of smart cities

(Source: Produced by authors based on Nagumo interview, Interview, July 3, 2024).

gies are resource-intensive and leave a noticeable carbon footprint (United Nations Environment Programme, 2024; Institute for Energy Research, 2023).

Although technology is a core component of a smart city, how it is selected and implemented, and how good governance, innovation, and development address the population's needs while maintaining community are equally important. Since smart cities go beyond technology, individual states implement smart city policies according to their capacity and constraints. Some cities utilize technology to address overpopulation in urban areas, whereas others, often found in Japan, utilize technology to address the consequences of an aging and declining population. Moreover, states may define a "smart city" in a manner that is more reflective of local norms. That is, for an international concept, it can be highly localized. The Smart City Institute of Japan, for example, approaches the smart city concept under the national "Digital Garden City Nation" policy, where the Government of Japan "aims to realize a 'fulfilling life' (Well-Being) by solving social issues and enhancing regional charm using digital technology" (Cabinet Secretariat's Office for the Council for the Realization of the Vision for a Digital Garden City Nation, 2022). The Smart City Institute of Japan has operated as a thought leader and agenda setter in Japan by:

1. Collecting, analyzing, and sharing the latest information on the world's leading smart cities and know-how for promotion;
2. Discussing, proposing, and advising for promoting smart cities in Japan; and
3. Promoting networking between various entities related to smart cities.

Takehiko Nagumo, founder and representative director of the Smart City Institute, contends the smart city concept is evolving and currently has five core components: 1) Well-being, 2) Innovation, 3) Sustainability, 4) Livable City, and 5) Resilience (Takehiko Nagumo Interview, July 3, 2024). Not all cities will have all five components and many smart city variations exist in Japan. Nagumo identifies at least three types of smart cities: Innovation-oriented, sustainability-oriented, and bed-town (sub-urban). As illustrated in Figure 1, different permutations of smart cities have different strengths and require different inputs. Innovative, sustainable, and resilient cities tend to lean on free market principles. Livable and resilient cities require strong civic engagement. And cities requiring high levels of innovation require inputs from the academic sector.

The FY2023-FY2027 Comprehensive Strategy for the Vision for a Digital Garden City Nation outlines four primary objectives: 1) create jobs in rural areas, 2) increase the flow of people to rural areas, 3) realize hope for marriage, childbirth, and child-rearing, and 4) enhance the attractiveness of every region.

The Ministry of Land, Infrastructure, Transport, and Tourism, especially its Urban Affairs Bureau, has also had a significant influence in promoting the smart city concept in Japan. This Bureau defines a "smart city" as "a sustainable city or district where management (planning, development, management, operation, etc.) is carried out while utilizing new technologies such as ICT to address various issues facing cities." The Urban Affairs Bureau further identifies the Internet of Things (IoT), robotics, AI, and big data as promising technologies for solving urban problems (Ministry of Land, Infrastructure, Transport and Tourism).

Of note, many of the cases in this article demonstrate how city governments

believe "green" cities will attract new residents, allowing them to address rural decline, aging populations, and other social issues. Japanese megacities, such as Tokyo and Osaka, are not often associated with the smart city concept, yet are innovation centers and promote climate-resilient infrastructure, technology, and green living. As a result, suburban and rural communities are using smart technologies and "green" marketing to attract residents away from major metropolitan centers. In a sense, environmentalism is imbued in smart city initiatives because they are attractive to younger Japanese and are not the end goal.

Smart cities in practice

Toyama City. Toyama City officially promotes itself as a "compact city," although official government documents use the term "smart city" regularly, if not interchangeably. A 2022 Smart City Vision Report, for example, introduced the idea of a "Toyama version of a Smart City." This tailored approach is common among Japanese smart cities as each aims to leverage its unique strengths to address the community's unique challenges. According to the *Resilient Toyama* report, resilience is measured in four categories: 1) resilient people, 2) resilient infrastructure, 3) resilient prosperity, and 4) resilient environment (Resilient Cities Network, n.d.). The report identifies two unique challenges to the region, demographic stresses and natural disasters.

Due to the anticipated decline in the overall population and growing aging population, government officials sought to shrink a city to better allocate resources to a needy population. Between 1995 to 2020, the population of Toyama city only decreased by less than 4,000 people (about 1%), but Toyama Prefecture's population decreased by 100,000 (about 9%) in the same period. Moreover, Toyama Prefecture has the 5th oldest population in Japan, with an average age of 48.6 in 2020 (City Population; Official Statistics of Japan, 2020). These trends also indicate that while a smart city aims to build a more attractive and citizen-focused city that reverses or at least limits population decline, this may come at the expense of surrounding communities as the smart city draws in population from them.

One of the main technologies implemented in Toyama City has been centralized public transportation (rail, taxi, bus, streetcars), with light rail transit (LRT) at its core, in part by taking over a defunct Japan Railways Group (JR) rail line. According to Shinji Honda (Senior Policy Supervisor, Toyama City), the city government sought to decrease reliance on cars and developed a public transportation system where public transportation was within walking distance; 300m from a high-frequency bus station and 500m from a train station (Shinji Honda Interview, July 18, 2023). The proximity to public transportation ensures that all residents, especially the elderly, have access to city amenities (Resilient Cities Network, n.d.). To determine where rail lines and bus routes should be placed, Toyama City utilized surveillance technologies to track where residents were traveling most. This data allowed the city to determine optimal operation times, and some routes started to operate on 15-minute intervals instead of the 30-60-minute intervals when they were run by the private sector.

Accessibility is also an important goal of Toyama City. For example, the city raised the platform on train and electric rail lines to ensure they were on the same level as the carriages. The leveled platforms helped the elderly and families use strollers to disembark more easily from trains. These changes have had a meaningful impact on public transportation use, with an increase of 2.1 times on weekdays and 3.3 times during weekends, with noticeably increased use from the elderly population (Shinji Honda Interview, July 18, 2023). LRT is not a new technology in Japan, but smarter leveraging of the technology and urban planning allowed the government to address the demographic crisis, place residents closer to city services, and increase the use of public transportation, all of which make the people and city more resilient to natural disasters and decrease their carbon footprint (Kriss et al., 2021).

Toyama City is a prime example of a smart city that utilizes existing technologies to develop an urban design plan sensitive to the city's large area, residents' habitual use of cars, and the aging and declining population. Moreover, according to Toyama City officials, the "compact city" concept begins with the city's needs, and the environmental benefits come second. This distinction is important because it reveals that environmental concerns do not exist in a vacuum, and cities are more likely to address them if they can also address economic and demographic concerns as well. These technologies are not aimed at climate resilience, but by drawing more residents to the core of the city, better understanding citizen behavior, decreasing reliance on vehicles, and making a city more "compact" overall, Toyama City is better positioned to address climate-related disasters.

To continue positive momentum, city planners must promote innovation and good governance. Developing new technologies ensures that cities have the latest tools to address a rapidly changing ecological environment, are economically competitive to attract residents and maintain a city's vibrancy, and strengthen public-government-private sector relationships. Smart cities have launched innovation hubs to allow each stakeholder to contribute their comparative advantages and synergize their interests. Toyama City, for example, launched an innovation hub that seeks to connect the public, academic, and private sectors to generate business opportunities and technologies for the future. Located near Toyama Station, the Sketch Lab is a moderately small space that regularly hosts workshops, talks, classes, and town development dialogues. In the Toyama City Smart City Vision interim report, city officials advocate for "citizen centrism," which is approaching the smart city vision from the service needs of civilians instead of contract obligations and interests of the state.

As Toyama City implements these bold technologies and initiatives, city officials must maintain good communication with the public to gain support for the smart city policies, justify expenditures, and ensure services are fully utilized. In Toyama City, the mayor held regular town halls to gain support and serve as a feedback mecha-

nism. The city also produces reports and communicates with the media to maintain high levels of transparency. As the population shrinks and budgets become increasingly strained, policies become more politically and economically costly because changing directions becomes more difficult. Climate change resilience, changing the direction of demographic decline, attracting new residents, and reinvigorating rural economies require multi-decade plans, and hence, sustained and robust engagement with the public.

Fujisawa Sustainable Smart Town (SST). Fujisawa SST, located in Kanagawa Prefecture south of Tokyo, opened in 2014 on the site of a former Panasonic factory and is home to around 1,000 households. Developed through a partnership between Panasonic, Tokyo Gas, Mitsui Fudosan, and other organizations, the town was designed with a 100-year vision emphasizing sustainability and adaptability (Fujisawa City, 2024). After 10 years, in October 2024, Fujisawa SST was completed (Panasonic Group, 2024). As such, Fujisawa SST's technological infrastructure focuses on smart homes equipped with Panasonic's integrated systems, including solar power generation, battery storage, and energy management technology. The adoption of these technologies falls under the city's branding of "smart life," "smart space," and "smart infrastructure."

Safety, sustainability, and resilience are key concepts in Fujisawa SST's approach to community building. For example, a monitoring system, including public space surveillance, oversees community services, while electric vehicle charging stations and bike-sharing systems support sustainable transportation. Fujisawa SST has attracted a younger population (~30% under the age of 30), located in the popular Shonan area with its beaches and within easy reach of Tokyo and Yokohama. This has also made it an important case study for Japan's aging population. The construction of new housing complexes for the elderly and the integration of intelligent healthcare services, including telemedicine options, demonstrate how technology can improve daily life (Hornyak, 2022). The concept of 'machi oya' or 'town parent' illustrates this approach to building community across generations. The town is jointly managed by the Fujisawa SST Council and the Fujisawa Management Company, which oversee day-to-day operations, collect data, and guide the town's development through regular town meetings and digital platforms (Wang, 2023). But this also means that corporate involvement represents a main element in the town's governance.

In addition to these local governance and community features, environmental sustainability is central to the community's design and operation. For example, homes are equipped with renewable energy systems (such as vehicle-to-house [V2H] systems that allow for charging EVs off solar panels and using EVs to power homes) and smart grid technology, reducing dependence on external energy sources and increasing resilience to natural disasters. Green initiatives are also incorporated into the overall design of the SST, with houses, roads, and walkways built to allow fresh air to circulate through the city. City planners take advantage of the region's geographic location and reputation as a beach town and promote a "green" aesthetic to attract young families, such as keeping telecommunications cables underground, installing thin-film solar panels on residential balconies, and curating specific lifestyle books in the community's bookstore. Finally, city designers hope SST will serve as an important innovation hub to foster public, private, and academic collaboration.

Much of the innovation from Fujisawa SST comes directly from Panasonic, as it can implement technologies in the city before they reach the mass market. The city also announced an innovation lab called "Future City Lab," led by Keio University and designed to connect residents, academia, industry, and government (PR Times, 2024).

Despite thorough planning and strong support from the private sector, Fujisawa SST faces significant challenges, particularly in terms of cost. Development and maintenance costs are substantial, and housing prices are about 10% higher than the regional average. City planners will need to address concerns about the model's scalability, particularly in regions with limited resources. The city's reliance on advanced technology requires constant updating and maintenance, creating ongoing financial costs, while higher living costs and technological requirements may limit accessibility for lower-income residents, potentially creating social inequalities. According to a Fujisawa SST guide during a site visit, approximately 80% of residents were satisfied with the city, whereas 20% were dissatisfied, most citing strict restrictions of home design as the source of their dissatisfaction. Maintaining interaction with neighboring communities to avoid becoming a gated community also poses a challenge. Here, sharing renewable energy resources, engaging in joint disaster drills, and providing access to the SST's welfare facilities are key mechanisms for fostering integration with the surrounding areas. Moreover, previous studies have also shown that despite extensive data collection and feedback mechanisms provided to citizens, citizen participation and stakeholder dialogue to implement community-related decisions remain limited (Wang, 2023). Despite these challenges, Fujisawa SST is a valuable model for smart city development, demonstrating how public-private partnerships and active community engagement can create resilient, sustainable urban environments (Hornyak, 2022; PwC, 2021).

Tsuchiyu Onsen. Tsuchiyu Onsen is not a city, rather, it is a remote foothill hot springs resort community within the municipal boundaries of Fukushima City, Fukushima Prefecture. It had been an independent village until it merged with Fukushima City in the 1970s. Like many other rural parts of Japan, this small hamlet is suffering from depopulation, with the population dropping from 380 to 300 residents between 2013 and 2023 (Tsuchiyu Onsen Interview 1, 2023).

For the last 1400 years, this community's main industry has been hot spring tourism, specifically onsen (hot springs) hotels and inns. Onsen boiled

eggs, a popular delicacy, are another related long-term industry. This community has turned to renewable energy to try to revitalize an aging community whose economy was hit hard by the Great East Japan Earthquake of March 11, 2011, with five of 16 onsen inns closing due to a lack of tourists (Rivero & Inumat, 2024). The local onsen cooperative took advantage of the Feed-in-Tariff (FIT) for renewable energy enacted in the wake of this triple disaster and technological advance. Specifically, it has embraced geothermal electricity generation.

This embrace has set Tsuchiyu Onsen owners cooperative apart from nearly all others in Japan, where opposition to geothermal energy is the norm due to concerns that geothermal plants damage the hot water resource that onsen hotels and onsen egg boilers depend on. According to Sato Yoshiyasu, Vice President of the Japan Onsen Association, "if possible, we want the drive for geothermal energy developments to stop" (Japan Times, 2023). Hotel owners have often alleged and worried that geothermal plants will cause their onsen water to go cold, even though there is little evidence that this is actually the case (Balmer and Ozawa, 2023). In fact, the opposition of onsen associations has been one of the leading obstacles to developing geothermal electricity in Japan. Given that geothermal, unlike wind and solar power, is a stable base load of power and that Japan has the world's third-largest geothermal resource, Tsuchiyu Onsen has attracted wide attention domestically and internationally as a model for Japan on how the harmonious coexistence of onsen resorts and geothermal plants can be achieved (Dickie, 2012; Balmer & Ozawa, 2023; Rivera & Inuma, 2024).

The Tsuchiyu Onsen association has not only tolerated the geothermal plant, it has been its main investor and the initiator of the plant since 2012 (Dickie, 2012). It founded a company, Genki Up Tsuchiyu (GUT), to build and manage the plant. It turned to new technology, specifically a binary geothermal plant, which uses a fluid that boils at a lower temperature than water to drive the turbine. A binary plant thus needs far less heat to generate electricity than earlier technology. The Tsuchiyu plant runs on steam, and excess water runs off from a well that supplies hot spring water to local hotels. The Tsuchiyu plant can generate up to 440 kw, or 2.6 Gwh per year, enough to power 800 homes. It could have been bigger, but a 500 kw capacity limit on the line linking the town to the regional Tohoku Electric Power Company grid caused Genki to limit the plant size rather than negotiate with Tohoku EPCO to build a bigger line. Nearby, GUT also has invested in a small-scale hydropower plant (144 kw capacity; 900 Mwh per year) in the town, entirely rebuilding a 52 kw hydro plant that had been shut down when Tohoku EPCO connected the town with its regional grid one hundred years earlier. In addition to the geothermal plant, GUT uses run-off hot water from its geothermal plant to run a shrimp farm. It also runs a cafe where customers can catch these shrimps for lunch (Tsuchiyu Onsen Interview 1, 2023).

This cafe, the shrimp farm, and especially the geothermal plant are featured as tourist attractions, together with the geothermal plant. GUT provides paid tours to 1000 tourists a year on average, many of whom stay at a local onsen inn. Their geothermal plant and shrimp business has also attracted national and international attention beyond extensive media coverage, with two Japanese Ministers of the Environment visiting, and a delegation from the International Renewable Energy Agency (IRENA) paying visits (Tsuchiyu Onsen Interview 1, 2023). This tourism strategy can also be seen as a strategy for realizing urban and national engagement. It is less clear whether this could also be a strategy for attracting new residents.

The 3-11 Great East Japan Earthquake, tsunami, and nuclear accident not only prompted the Tsuchiyu onsen cooperative to search for a way to revitalize the town and stop its demographic decline, but it also removed obstacles and created opportunities for doing so. Specifically, regulatory reform after March 11, 2011, allowed for the building of geothermal plants in national parks for the first time, and Tsuchiyu Onsen inside the Bandai-Asahi National Park. Also, the Feed-in-Tariff (FIT) enacted by the Japanese government in 2012 for promoting renewable energy means that since the Tsuchiyu geothermal plan opened in 2015, it has received 40 Yen for each kilowatt-hour it sells to Tohoku EPCO. After this FIT rate runs out in 2030 and GUT only receives a much lower wholesale rate, it is considering establishing a local electricity company, purchasing some electric vehicles for local electricity storage, and building a smart micro grid for the community to ensure that more of its electricity is consumed locally and to enhance local disaster resilience, so that this community does not lose power for several days as it did after 3-11. GUT also has expansion plans, including an additional 100-kw of geothermal capacity and 360 kw of new small-scale hydro capacity, but needs to attract financing (Tsuchiyu Onsen Interview 1, 2023).

GUT and its geothermal and hydro plants resulted from community engagement, specifically through the onsen cooperative, and GUT, although a for-profit company, does provide for the community. Specifically, with local schools closed due to population decline, it funds bus travel for local children to schools outside of the community. It also covers public transportation expenses for the elderly. Nonetheless, a co-owner of a local onsen inn complained that GUT should pay out more of its profits to support the local community, such as by paying for the community's street lights (Tsuchiyu Onsen Interview 2, 2023). The founding goals of GUT in 2012 in many ways resemble those of a smart city. According to its website :

"1. To build a model future onsen tourism region. 2. To respond to the declining birthrate and aging population in society. 3. To create an eco-town using natural renewable energy. 4. To collaborate with industry, government, and academia." (Genki Up Tsuchiyu, n.d., author's translation)

GUT thus represents an attempt by a community, specifically a local onsen cooperative, to slow, if not reverse, local population and economic decline. To accomplish these goals it has turned to new renewable energy tech-

nology, specifically, binary geothermal technology, along with small-scale hydro, to create an electricity-generating business and related shrimp farming and tourism promotion business. It is now working on expanding its renewable electricity business, and in several years, establishing a smart microgrid and local power company. Some of its profits are returned to the community through subsidizing public transportation for the old and the young and providing profit to the onsen cooperative. It is thus an example of promoting social inclusion and community participation from its inception as a local initiative, through its support for the young and elderly, and through promoting social links with urban and other areas. In this sense, GUT can be said to represent a "smart community," one that embodies our policy recommendation about community involvement and communication.

Conclusion and policy recommendations

Japan provides several cases that are highly informative of the diverse ways cities implement technologies for climate-resistant infrastructure. Broadly speaking, Japanese cities are looking to develop resilient infrastructure as the country is highly vulnerable to natural disasters and climate change. Tokyo, which is usually not considered a "smart city," launched its SusHi Tech initiative, which leverages technology to build a more resilient infrastructure. However, climate change does not impact each city in the same way. Coastal cities are sensitive to rising water levels, whereas historically cold regions of a country will need to adjust to rising temperatures and new seasonal patterns. Despite the aggregative dangers posed by climate change, city design must also consider a region's comparative advantages (geothermal energy) and vulnerabilities (aging and declining populations). As a result, each city will need to tailor its infrastructure policies to its specific economic, political, and social contexts.

Toyama City, Fujisawa SST, and the Tsuchiyu Onsen projects demonstrate just a few of the technologies being tested in cities across Japan. They demonstrate how cities can cut costs, strengthen networks, revitalize economies, attract residents, and build climate resilience while tailoring their politics to specific economic, political, and social contexts.

Nevertheless, innovation and technology are not a panacea for all of Japan's demographic problems. A drawback of heavy reliance on technology is that communities may weaken if in-person interactions decrease. Using drones, remote work, and relying on digital communication may decrease the human resource requirements to run a city, but this can increase the sense of isolation among the elderly.

The challenges of social inclusion and participation can be addressed with participatory urban planning. For example, one digital twin project in Japan – Project PLATEAU – generates a large-scale simulation that can simulate various socioeconomic activities, such as human mobility and economic transactions so that planners can use the results for actual urban planning. However, this simulation is highly dependent on data. Thus, if these activities are poorly digitized, they are hard to simulate and include in future urban planning. Potential subgroups of populations at risk of losing from smart city projects include informal sector workers, homeless people, seasonal workers, and foreigners (Haraguchi et al 2024). These social groups are often underrepresented in data, posing challenges for data-driven planning and smart city development. Nonetheless, some projects in Japan, such as the Daimaruyu Project surrounding Tokyo Station, are beginning to address this challenge by incorporating these underrepresented social groups in their smart city project.

Another threat to communities is the violation of privacy. One of the key goals of the smart city project in Japan is to enhance preparedness and responses to natural disasters as the county is highly vulnerable to disasters. For example, real-time analysis of human mobility during disasters would provide city officials with valuable insight into chaotic post-disaster situations (Haraguchi et al., 2022). To prepare for this, human mobility data should be analyzed both during disasters and in normal circumstances. Yet, ensuring individual privacy remains a major concern in various smart city projects worldwide, and it has been a key factor in the failure of some smart city projects. For example, a high-profile project by a sibling company of Google in Toronto, Canada, was canceled due to privacy concerns raised by citizens and advocacy groups (Bilefsky, 2019). Common privacy concerns include data security, commercial use of data, government surveillance, consent and transparency, data retention, and access, among others. Approaches to address this include building trust among citizens through participation (Lucas and Simpson 2024) and using synthetic data with a task-based approach (Papyshev and Yarime 2021) and differential privacy techniques (Savi et al., 2023).

In sum, technology and climate resilience must come second to community and good governance. The tools will not be utilized effectively, and the objectives will not be achieved if stakeholders are not fully committed. The "smart" in smart cities comes from the people, not the technology.

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