IN THE EYE OF THE STORM

How centuries of disaster make Tokyo a case study in urban resilience

Urban Land Institute

COVER: *The Great Wave Off Kanagawa* by Hokusai - displayed in the Metropolitan Museum of Art in New York City.

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Introduction

The sleepy castle town of Edo, as Tokyo was once known, started life as an innocuous fishing community before its adoption as the family seat of the local Tokugawa clan in the early 17th century kicked off a 100-year period of growth, rapidly transforming it into the world's most-populous city.

Even in its early days, however, Tokyo seemed a magnet for misfortune. Frequent natural disasters – ranging from flood to fire to drought – have struck the city over the centuries, with increasingly serious consequences as it grew in size.

Tokyo's familiarity with catastrophe stems from a variety of factors. Its proximity to inland mountain ranges means runoff from the area's many torrential storms quickly inundates the city's low-lying floodplain. In addition, underlying geologic fault lines pose extreme danger from earthquakes, which in turn aggravate the threat from what historically have been the biggest risk of all – raging fires among the city's traditional wooden buildings. More than 100 major fires destroyed large parts of the city in the Edo period alone, causing hundreds of thousands of deaths. It was this familiarity with disaster that prompted clan leaders to establish an early framework for urban resilience that has lasted to the present day.

Among other things, this framework involved adoption of an urban planning strategy that left many neighbourhood plots empty as a way to stop rapidly spreading fires. In addition, local authorities moved to establish the world's first fire brigades, with stations created throughout the city beginning in the 17th century.

Since that time, resilience efforts have gone from strength to strength. In the second half of the 19th century, several massive civil engineering campaigns were launched. These included construction of an extensive array of landfill projects, river diversions, massive moats, and a network of canals both inside and outside the city. The aim was both to protect against floods and to provide the city guaranteed supplies of fresh water.

More recently, and partly as a byproduct of the huge fiscal stimulus programme launched by the Abe administration following the global financial crisis, the government sponsored another batch of infrastructure initiatives, again mostly aiming to protect against the threat posed by too much or too little water.

This longstanding commitment to creating the hardware of resilience, in conjunction with the engineering know-how needed to design and build it, is one reason the city stands today as one of the most resilient in the world. Hardware is only one part of the equation, however. The other is the city's psychological strength – an inherent toughness in its people, again born from long experience with catastrophe, that continues to shape communal behaviour in the form of ongoing cultural and social norms. It is this combination of physical and cultural preparedness that has made Tokyo uniquely adapted to survive a persistently hostile environment.

Contemporary hand scroll of the Great Fire of Meireki. (Wikipedia/Tashiro Koshun)

Map of Edo in the 1840s. (Wikipedia/UT Library Online)

There are many modern-day examples of how historical practices continue to boost Tokyo's resilience against disaster. For example, the Japanese cultural foundation of insular villages (known as *shuraku shakai*), which once formed the earliest working micro-units of Japanese society, lives on today in countless modern-day festivals overseen by neighbourhood associations and volunteer fire brigades. Despite their traditional trappings, however, the role these festivals play in modern society is more than just symbolic. By creating an enduring social nucleus, they continue to serve a more practical function by providing organisational frameworks that allow grassroots communities to pull together in times of crisis.

Chapters 1 and 2 of this report examine how this unique combination of hardware and software combines to make Tokyo so resilient, protecting it against a wide variety of seismic-, fire-, and water-related risks.

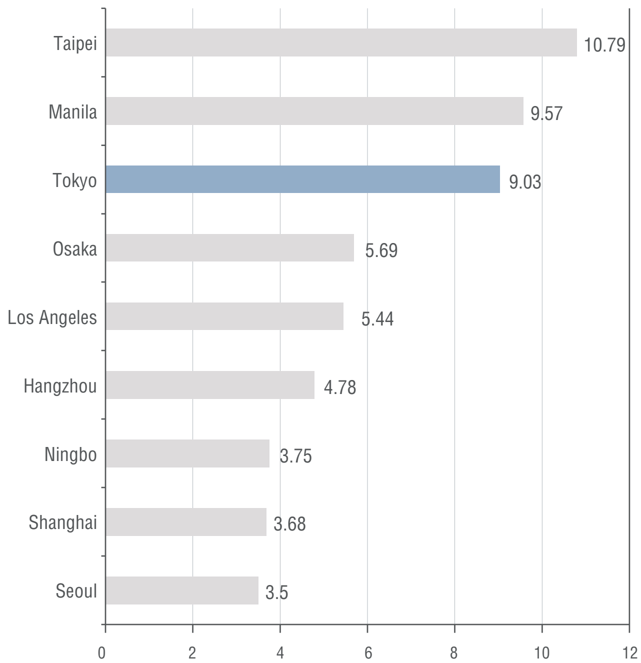
Chapter 3 analyses how three of the country's leading developers – Mitsubishi Estate Group, Mori Building Company, and Mitsui Fudosan – play their own unique roles in delivering resilient outcomes. These companies not only incorporate the highest levels of resilience in their own projects, but also ensure that surrounding neighbourhoods benefit too, creating local bubbles of self-reliant infrastructure that can function independently of the city's utilities and communications infrastructure if needed.

Chapter 1: The Hardware of Resilience

With its long history of calamity, Tokyo has always been in the eye of the storm. According to the Lloyds City Risk Index – which measures resilience globally against 22 manmade and environmental threats – the Japanese capital ranks third behind only Taipei and Manila from risk of natural disaster.

Global Cities Most Threatened by Natural Disaster

(Annual economic output at risk from potential one-off events, in billions of U.S. dollars)



Source: Lloyds and Cambridge Centre for Risk Studies, 2018.

This reflects in part the city's sheer size: with some 37 million inhabitants, Greater Tokyo is Asia's largest urban area. More important, though, are Japan's geology and geography. Its position on the Asia Pacific 'Ring of Fire' – a long subduction zone stretching from New Zealand to Alaska – means it hosts about 10 percent of the world's active volcanoes and is hit by as many as 1,500 earthquakes annually, many of them sizeable events ranging in magnitude from 4.0 to 6.0 on the Richter scale.

In addition, with major subterranean fault lines located less than 100 kilometres offshore, the coastline is at constant risk from tsunamis. Most recently, in March 2011, the Great East Japan Earthquake, the fourth-largest event ever recorded, generated massive waves that devastated large parts of Japan's northern shores.

Finally, Tokyo's longstanding exposure to extreme weather has been compounded in recent years by stronger and more frequent storms. Although a link to climate change is still unproven, a recent study by the Japan Meteorological Agency showed the average number of days in Japan with rainfall events of 50 millimetres or more was about 1.4 times higher in the 10 years through 2018 than in the period 1976–1985. Not only that, but the number and intensity of extreme weather events have increased.

Tokyo's Disaster Risk by Type

(Annual economic output at risk, in U.S. dollars)

Tropical windstorm	$3.35 billion
Flood	$1.94 billion
Earthquake	$1.89 billion
Volcano	$948 million
Tsunami	$389 million
Drought	$311 million
Freeze	$138 million

Source: Lloyds and Cambridge Centre for Risk Studies, 2018.

Despite multiple threats, however, and the remorseless growth of its built environment, the city in recent years has managed to dodge the bullet. During the 2011 earthquake, for example, the city experienced severe shaking but minimal physical damage. Similarly, the 2019 arrival of Super Typhoon Hagibis – one of the largest storms ever recorded – caused extensive flooding across parts of northern Japan, but again left the capital largely unscathed.

From an infrastructure standpoint, Tokyo's resilience to this array of natural dangers is a product of several factors. Government commitment to building the required hardware provides the overarching theme, while a focus on innovation, long-term investment, and willingness to learn from past events are other key elements.

Regulatory Framework

Disaster management in Japan is overseen by the Cabinet Office (*Naikakufu*), in collaboration with a number of other governmental and nongovernmental agencies. In particular, the Central Disaster Management Council, chaired by the prime minister, is responsible for all aspects of disaster management policy, including creation and promotion of the country's Basic Disaster Management Plan, a document that attempts to project the likelihood of various types of natural disasters, as well as the logistics needed to accommodate the government response. This allows authorities to react quickly once an event occurs, both in overseeing emergency relief and supporting victims.

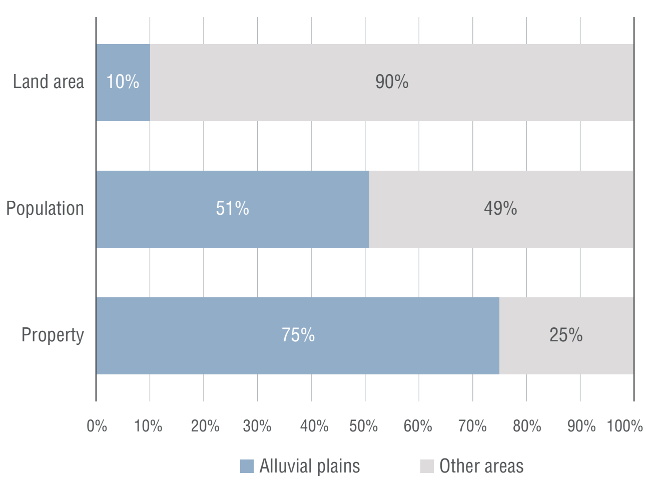
The council also helps residents and officials prepare on a local basis to manage the consequences of floods, earthquakes, volcanoes, and other disasters.

Risk: Floods

The danger from floods in Japan has always been extreme. For the most part, this is the result of regular high-intensity rainstorms, including typhoons, although one-off events such as tsunamis and earthquakes (which destroy both coastal and inland levees) create other obvious flood risks.

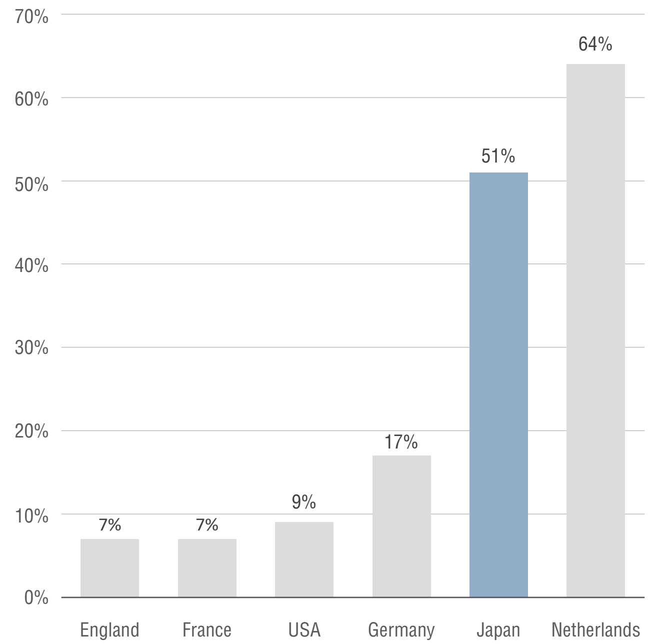
More fundamentally, though, flood danger is a function of Japanese geography. The fact that so much of the country consists of steep mountainous terrain means that about 75 percent of Japan's urban areas have been squeezed onto just 10 percent of its land, usually along low-lying coastal areas or floodplains constantly at risk of inundation. In addition, because Japan's mountains are located relatively close to the coast, its rivers tend to be unusually short and steep. This leads to rapid rainwater runoff and a wide divergence between minimum and maximum water flow rates, leaving affected communities little time to evacuate. Flooding risks are also amplified by minimal natural water retention of the land, especially in the mountains.

Japan: Distribution of People and Property between Alluvial Plains and Other Areas



Source: Public Works Research Institute.

Percentage of Population Residing in Floodplain



Source: Ministry of Land, Infrastructure, Transport, and Tourism.

In the cities, meanwhile, ongoing urbanisation has impeded creation of coherent drainage infrastructure. This is partly due to the elimination of so many rice fields and forests that functioned traditionally as natural stores of rainwater, and partly a side effect of historical and cultural norms. Although Japan has long had city planning laws, for example, large-scale urban development has often been frustrated by the multitude of private landowners that continue to control the disposition of rice paddies lying on the edges of urban areas. Cities, therefore, expand incrementally and in ad hoc ways, frustrating creation of complementary interconnected drainage networks.

Investment Initiatives

While flood control has always been a priority in Japan, efforts have been stepped up over the past 30 years, with both the national and Tokyo governments investing heavily in infrastructure as part of a comprehensive strategy to replace aging facilities and accelerate stormwater runoff. One reason for this is that infrastructure construction has become an important component of government economic stimulus.

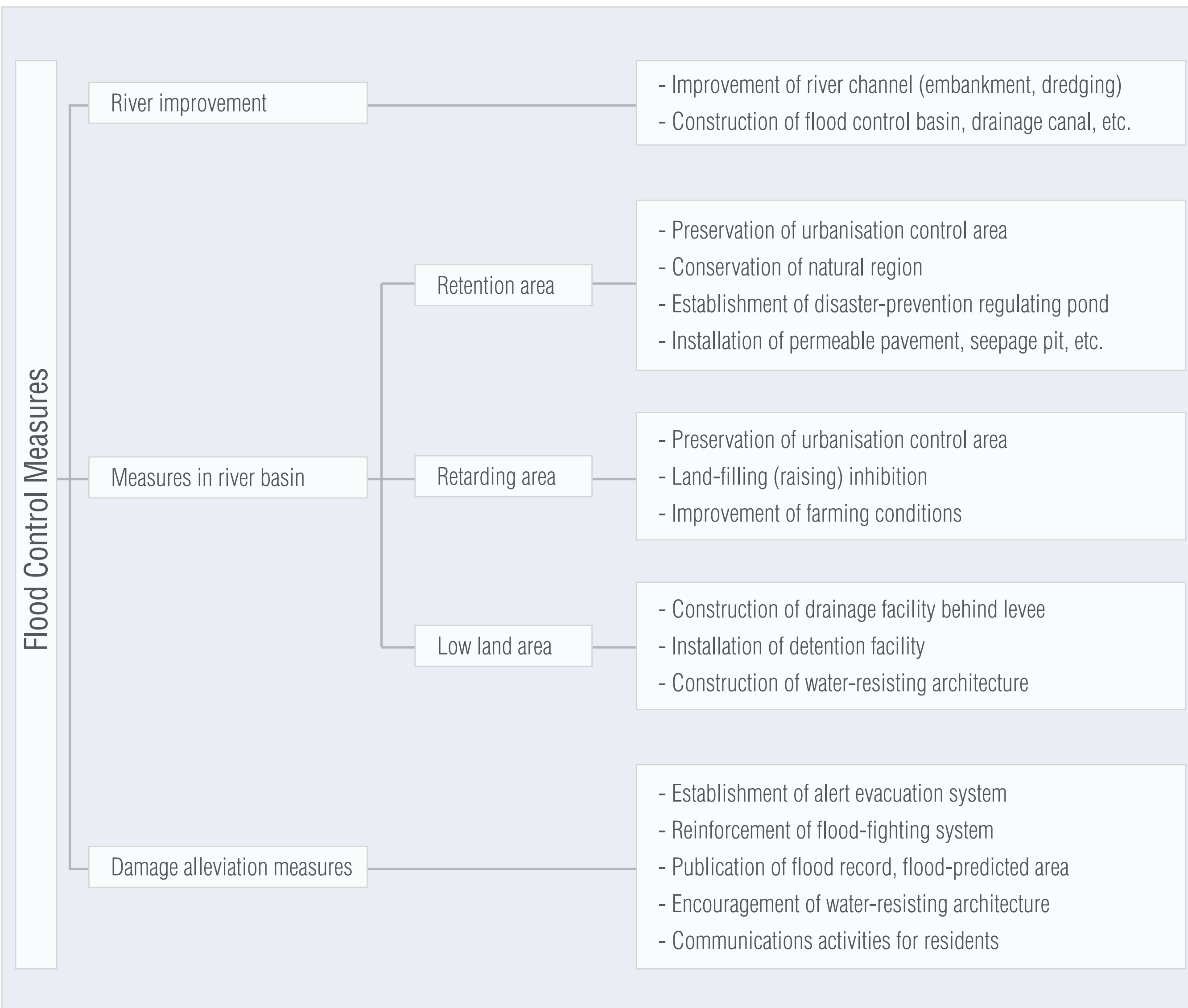
Upstream, flows are controlled by improvements to river channels, construction of multipurpose dams (i.e., for flood control, water retention during droughts, and hydropower), as well as the introduction of 'super levees' – embankments with crowns as wide as 300 metres. These super levees are not only resistant to both earthquakes and overflows from major storms, but also provide new land that can be put to public use in urban redevelopment projects.

Downstream, the emphasis is on construction of a sophisticated network of diversion channels and water retention infrastructure in individual river catchments. Because land supply in urban areas is so tight, most facilities are built deep underground – a time-consuming and costly exercise.

The extent and quality of resilient infrastructure that Tokyo has created in this way is remarkable. According to official figures, as of 2020, the city had 28 regulating reservoirs with capacity of some 2.56 million cubic metres. Plans currently in place involve building at least 10 more facilities that will increase capacity to a massive 8 million cubic metres.

Infrastructure at the local level is equally important, with a focus on creating a multitude of small-scale neighbourhood projects to provide coping capacity. These include a wide range of targeted features such as permeable pavements, infiltration pits and trenches for individual residences, large-capacity U-shaped gutters to channel runoff from streets into urban canals, and multipurpose playgrounds, sport grounds, parks, and inner-city paddies that act as emergency retarding basins. Even with this level of preparation, ground floors of new housing are often elevated above street level to prevent water ingress. Metro lines, meanwhile, are equipped with removable weirs, and essential roads are elevated to help with evacuation during emergencies.

Comprehensive Flood Control Measures



Source: Public Works Research Institute.

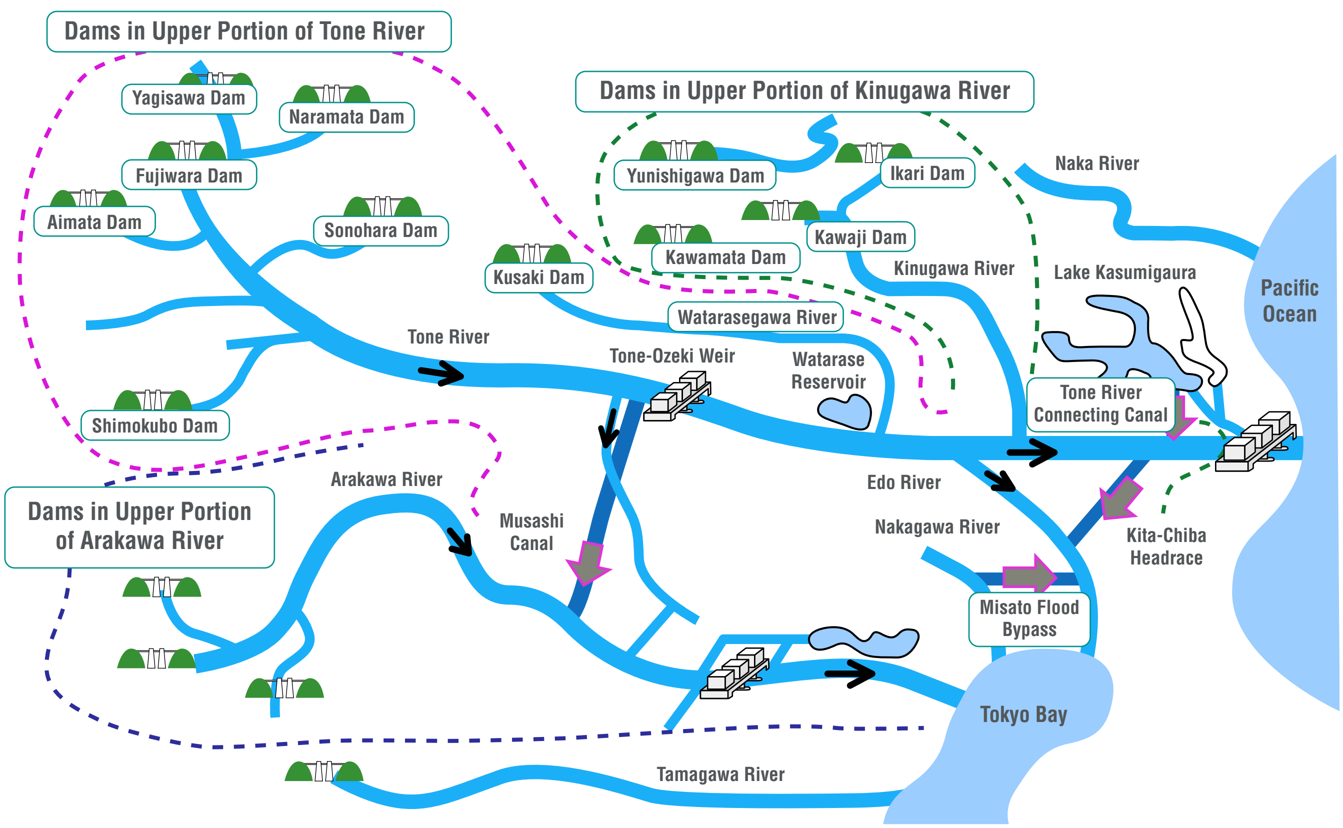
The effectiveness of the government programme can be seen in a before-and-after comparison of the outcome of modern-day storms: not only has the number of deaths from rain and floods fallen precipitously from levels in the 1950s and 1960s, when casualties frequently reached the thousands, but property damage is also far lower. During Typhoon 18 in September 1991, for example, Greater Tokyo saw a total of 186.5 millimetres of rainfall over local river basins during a 48-hour period, flooding more than 31,000 homes. After Tokyo had completed large parts of its current flood management infrastructure, however, a similar storm (Typhoon Lan) in October 2017, which dumped 189.7 millimetres of rain over the same area and during a similar time frame, flooded only 202 homes.

Examples of individual water control programmes follow.

Tone River System Catchment

The Tone River is the most important waterway system in Greater Tokyo and has been the target of several major water management projects that aim to balance overall water supply and demand. Managed by the national government, the river and its associated drainage network comprise six rivers and five river systems, which also supply water to consumers in the south by transferring supply to the Edo River via the North Chiba Canal. Supplies in the Tone River network are controlled by way of eight upstream multipurpose dams that regulate supply levels for both consumer and agricultural purposes.

Tone River System Catchment



Source: Ministry of Land, Infrastructure, Transport and Tourism.

Kanda River/Loop Road 7 Underground Regulating Reservoir

Phase 1 of the Kanda River project (also known as the Yamanote Tunnel) opened in 1997 and consists of a 12.5-metre-diameter, two-kilometre-long underground reservoir leading from the Kanda River (a 24-kilometre watercourse in northern Tokyo) with capacity of 240,000 cubic metres. It differs from the Outer Area Underground Discharge Channel (see below) in that regulating reservoirs do not shift floodwater to other locations but simply hold it temporarily, after which water is pumped back to the surface. Phase 2 of the project was completed in 2019, extending the reservoir by 2.5 kilometres and boosting capacity by 300,000 cubic metres.

Five similar regulating reservoirs under construction will create an approximately 30-kilometre-long, 10-metre-wide underground waterway running from the Shirako River in Itabashi Ward in Tokyo's northwest all the way to Tokyo Bay. It is responsible for preventing overflow from 10 different waterways and is designed to handle flash rainstorms with intensities of at least 75 millimetres per hour.

Arakawa No. 1 Detention Basin

Another way to deal with urban flooding is through use of detention basins, which temporarily store water in open spaces used normally as public facilities such as parks, playgrounds, parking lots, etc. Technical guidelines created by the government have established specifications for such multipurpose facilities since the late 1980s. Although detention basins were originally small scale, they have gradually become increasingly larger and more sophisticated, and now commonly double as artificial wetlands that support local wildlife and habitat. One example is the Arakawa No. 1 Detention Basin, located in Saitama Prefecture just upriver of Tokyo, which was completed in 2003 after 34 years of construction. Though rarely needed, the basin was able to successfully divert and store some 350 billion cubic metres of water during typhoon Hagibis in 2019, preventing extensive flooding in the local area. The facility normally serves as a public park and baseball centre.

Greater Tokyo Outer Area Underground Discharge Channel

Geographically, the river basins of Tokyo's Naka and Ayase rivers are relatively flat. This has helped ensure fast urbanisation as Tokyo's urban footprint extends outward, but has also caused frequent inundation when fast-flowing water arrives from storm runoff in the mountains. To help address this, authorities have built what is now the world's largest underground flood control facility, the Greater Tokyo Outer Area Discharge Channel. The project opened in phases from 2002 to 2006 in Kasukabe City, a commuter town about 45 kilometres north of Tokyo.

The Greater Tokyo Outer Area Discharge Channel is the world's largest underground flood control facility. (Manuel Ascanio/Shutterstock)

Consisting of a series of five 70-metre-high vertical silos linked by a 6.3-kilometre tunnel running 50 metres beneath Highway 16, the channel is a high-tech pressure-adjusting facility that uses four powerful gas turbine pumps to divert floodwaters southwards from the local river network into the more accommodating Edo River at a rate of about 200 cubic metres per second. Construction costs of ¥230 billion (about US$2.1 billion) were hefty, but the channel has already been put to use more than 100 times since 2002, and government projections suggest that over a period of 50 years, the project will have recouped more than three times its construction costs in mitigated flood damage.

Following completion of the project, the average number of local homes damaged by flooding fell from about 7,000 per year between 1974 and 1984 to an average of 950 per year between 2007 and 2016. This newly created resilience has allowed nearby Kasukabe City to evolve in recent years as a successful logistics centre.

Tsurumi River Detention Basin

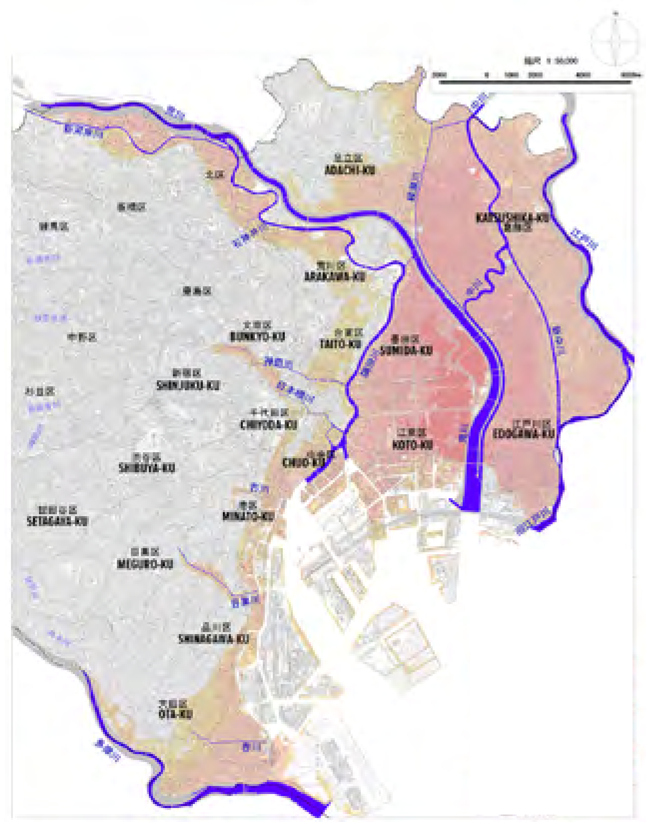
Serving a function similar to that of the Kasukabe Discharge Channel, this facility incorporates a 3.9 million-cubic-metre overflow storage basin that mitigates flooding from the Tsurumi River (on a once-every-150-year basis) as part of the construction programme for the adjacent Yokohama International Stadium. Though the project was not completed until 2003, land acquisition efforts began as early as 1985. The 84-hectare basin incorporates extensive sports fields, and integrated roadways have been built along its perimeter embankment and on elevated pylons within the basin itself to ensure that they remain above floodwater level. Buildings within the basin are also elevated on pylons. An outlet gate allows water to be released back into the river once floodwaters have receded.

Continuing Risks

Despite these large investments in new water storage and diversion infrastructure, the potential for storm-related flooding in Tokyo can never be eliminated. Aging upstream levees are increasingly prone to bursting (at least 55 breaches were recorded during Typhoon Hagibis alone). Downstream, flood risk is also set to rise, partly because typhoons and other extreme events are projected to increase in frequency over time, and partly because large parts of the city lie on floodplains that often sit below sea level. The Arakawa River, for example, which runs through the eastern part of the city, regularly reaches dangerous levels during storm surges, notwithstanding various large floodwater engineering projects already undertaken by the government.

In March 2018, the Tokyo Metropolitan Government published results of a flood simulation based on a worst-case scenario in which a large typhoon simultaneously causes both heavy rain and tidal flooding. The model projected that about one-third of central Tokyo's 23 wards would be inundated, including 90 percent of the Sumida, Katsushika, and Edogawa wards (where floodwaters were estimated to reach a depth of 10 metres in places), together with parts of the Marunouchi, Shimbashi, and Ginza downtown districts.

Moreover, though the Building Standards Act sets comprehensive requirements for mitigating risks from earthquakes and fires, until recently it contained no equivalent provisions to address risks of flooding. As a result, developers have often installed electrical equipment at ground or basement level rather than upstairs. Only after flooding inundated a residential development's underground machine room during Typhoon Hagibis did the government amend the Building Standards Act to include new rules that will now protect buildings against flooding risk.



Tokyo storm surge hazard map. (Tokyo Metropolitan Construction Bureau, River Department Planning Division)

Risk: Drought

Although flooding is the most obvious risk for water-related disasters, the country is also subject to periodic episodes of drought. According to official figures, average annual per capita precipitation of around 5,000 cubic metres is less than one-third the global average. In modern times, drought conditions are also aggravated by the heat-island effect experienced by modern cities.

One recent major drought-relief project involved efforts to maintain the flow of the Arakawa River. Following a March 1997 drought, authorities undertook a detailed analysis of river flow rate and projected water use. The subsequent opening of the Urayama Dam in March 1999 and the Takizawa Dam in March 2011 increased storage capacity of reservoirs along the Arakawa River network by about 4.7 times to 144.6 million cubic metres, thereby reducing water shortages across the river basin.

Risk: Earthquakes

With two major tectonic plates meeting almost directly beneath Greater Tokyo, the city has long been prone to major earthquakes. According to Japan's Headquarters for Earthquake Research Promotion, there is a 70 percent chance of a large inland earthquake with an epicentre below the Tokyo metropolitan area occurring before 2050. Realistically, no amount of preparation can adequately moderate the impact of a magnitude-7.0 event. Still, if any city is ready for earthquakes, it is Tokyo.

Building Standards Act

Japan's Building Standards Act is among the strictest such legislation in the world, setting out minimum thresholds to be met for the stability, strength, and rigidity of Japanese buildings and building components. It requires, among other things, that there should be 'little damage' in the event of a medium-sized earthquake, and that buildings should not be subject to collapse in major earthquakes of the kind that may strike once in hundreds of years.

Following extensive retrofitting in the wake of previous major earthquakes, some 87 percent of buildings in Tokyo now incorporate modern anti-seismic standards, according to a study by Tokyo University. As a result, even in the case of the Great East Japan Earthquake of 2011 – at magnitude 9.0, the strongest earthquake ever recorded in Japan – there were no collapses of institutional-grade buildings, either near the epicentre or in Tokyo itself.

The danger from seismic events means that modern buildings in Tokyo tend to be built with a lower profile than those in other countries (although advances in design technologies mean the skyline is creeping ever higher). For obvious reasons, building standards are stricter for taller structures (those over 60 metres high), which are designed to sway but not fail.

In general, high-rise buildings are more exposed to dangers posed by 'long-period' vibrations that emanate from earthquake epicentres located some distance away than they are from closer, 'near-field' events that may be more violent in themselves but produce rapidly repeating vibrations that pose less threat to structural integrity.

As a rule, high-rise buildings in Tokyo incorporate any or all of three different technologies to make them earthquake resistant:

1. The most basic technique is to reinforce walls and/or load-bearing pillars with a range of anti-seismic features, either by stiffening them using steel braces, or through installation of viscoelastic materials that absorb seismic energy to prevent structural failure.
2. Different types of damping devices can also be installed. These aim to dissipate lateral movement in building structures caused by 'long-period' vibrations, although they are also effective against high winds. Modern dampers usually consist of oil-filled, shock absorber–type fixtures deployed surrounding the building core on multiple floors of

Estimated Casualties and Property Damage in Tokyo Resulting from Direct Hit by a Major Earthquake

		Cause	Earthquake directly hitting Tokyo		Submarine trench earthquake	Earthquake occurring in an active fault
			Tokyo Bay North Area Earthquake (M7.3)	Earthquake beneath Tama (M7.3)	Genroku Type Kanto Earthquake (M8.2)	Tachikawa Fault Zone Earthquake (M7.4)
Casualties	Deaths	**Total**	9,700	4,700	5,900	2,600
		Quake	5,600	3,400	3,500	1,500
		Fire	4,100	1,300	2,400	1,100
	Injured	**Total**	147,600	101,100	108,300	31,700
		Quake	129,900	96,500	98,500	27,800
		Fire	17,700	4,600	9,800	3,900
		Severely injured	21,900	10,900	12,900	4,700
Property damage	Buildings damaged	**Total**	304,300	139,500	184,600	85,700
		Quake	116,200	75,700	76,500	35,400
		Fire	118,100	63,800	108,100	50,300
Evacuees (peak: the following day)			**3,390,000**	**2,760,000**	**3,200,000**	**1,010,000**

Source: Tokyo Metropolitan Government.

the structure. Fitting them is not a requirement, but they are common in higher-grade buildings. Over the past decade, these viscous dampers have become increasingly popular because they respond better to quakes across the seismic-intensity scale than do other types of damper, such as those using viscoelastic material. Sometimes, especially in the tallest buildings, 'tuned mass dampers' are also installed, usually on rooftops. These act as pendulums to absorb energy by swaying in the opposite direction to the swing of the building.

3. Technologies installed in building foundations involve a variety of 'seismic isolation' devices (either elastic or sliding) ranging from laminated rubber, ball bearings, springs, or viscous dampers that absorb ground movement and, in effect, separate the building structure from contact with the ground. In more sophisticated buildings, these serve to isolate shock waves by actively controlling the movement of the building itself.

Testing and certification systems are in place to ensure compliance at both the design and construction stages, as well as after construction is completed.

The Building Standards Act also provides basic rules for building construction practices that stipulate minimum engineering safety requirements against fires, earthquakes, and other natural disasters. Properties have a specified *kenpeiritsu*, which is the maximum building footprint-to-land ratio, and *yosekiritsu*, which defines the maximum total floor space allowed on a plot of land. Zoning rules determine what can be built on site and set out specifications for provision of sunlight, road size, fireproofing, etc.

Retrofitting Older Structures

For older buildings completed before the introduction of newer standards (in particular, those introduced in 1981 and in the wake of the Kobe Earthquake in 1995), the 1995 Law for Promotion of Renovation for Earthquake-Resistant Structures requires that buildings be assessed and, if necessary, structurally reinforced.

Though the programme is considered a success, retrofitting so many of the city's buildings in this way is an expensive process that remains a work in progress. According to a Japanese government audit released in late 2019, about 2,500 high-risk large buildings in Greater Tokyo were compliant only with pre-1981 building codes and had either not implemented seismic retrofitting or not replied to official enquiries relating to upgrading work.

Earthquake-Resistance Status of Tokyo Buildings

Type of building	Quake-resistance rate					
	Current status		Target			
			End of FY2016	End of FY2019	End of FY2020	End of FY2025
Designated buildings along emergency transportation roads	Dec. 2015	80.9%	—	90%[1]	—	100%
Buildings along emergency transportation roads	Mar. 2015	79.7%	—	—	—	90%[2]
Housing	Mar. 2015	83.8%	—	—	95%	[3]
Apartment buildings	—	—	—	—	95%	[3]
Main public housing	Mar. 2015	83.7%	—	—	95%	[3]
Tokyo public housing	Mar. 2015	82.7%	—	—	100%	—
Designated buildings	Mar. 2015	85.6%	—	—	95%	[4]
Public buildings important for disaster prevention	Mar. 2015	96.7%	100% (to be completed as soon as possible)			
Tokyo disaster base hospitals	Sep. 2014	87.8%	—	—	—	100%
Social welfare facility	Oct. 2013	94.1%[5]	—	—	100%	—
Nursery centre	Oct. 2013	89.8%[6]	—	—	100%	—
Private school	Apr. 2015	92%	—	—	100%	—

Source: Tokyo-Earthquake Resistance Promotion Plan, revised March 2016.

[1] 90% quake-resistant rate and resolution of high risk of collapse in tall buildings (buildings with seismic index value equivalent to less than 0.3).

[2] A target of 100% quake resistance by FY2025 or later has been set for buildings along emergency transportation roads, though specific goal year and goal value will be prescribed in the next and following revision to the plan.

[3] Overall resolution of inadequate quake resistance in housing by the end of FY2025.

[4] Targets for the end of FY2025 will be prescribed in the next and following revisions to the plan.

[5] Current quake-resistant rate for social welfare facilities, etc. (mainly residential facilities used by people requiring special assistance in disasters) is as of Oct. 1, 2013 (as calculated by TMG based on the number of valid responses in the Ministry of Health, Labour, and Welfare's investigation results).

[6] Current quake-resistant rate for nursery centres is as of Oct 1, 2013 (as calculated by TMG based on the number of valid responses in the Ministry of Health, Labour, and Welfare's investigation results).

Source: Tokyo Metropolitan Government.

Smaller buildings are also subject to safety regulations. For Tokyo's many traditional wood-framed homes, building standards were updated in 2000. Although widely believed to be either naturally resistant to earthquakes or resilient because they feature earthquake-resistant walls engineered for seismic strength, the city's wooden buildings commonly fail to meet regulatory standards, especially if built before 1995. In addition, the multitude of neighbourhoods featuring tightly packed wooden houses (totalling an area of about 13,000 hectares) continue to pose a major fire hazard, as evidenced by the tens of thousands of people who died in firestorms caused by the Great Kanto Earthquake in 1923.

As part of efforts to reduce fire risk, the Tokyo government since 2013 has designated 3,100 hectares in 53 areas considered to be at particular risk as 'Priority Development Districts', where buildings are either rebuilt or their fire resistance levels raised.

In addition, authorities have designated about 25 kilometres of roads in wooden-house neighbourhoods for upgrade to serve as inter-neighbourhood firebreaks. Certain roads have also been earmarked for widening so they can better accommodate emergency vehicles while also serving as local firebreaks. Such efforts have been reinforced by the upgrading of buildings adjacent to such roads to higher fire and earthquake resistance standards.

One way to facilitate these upgrades is to offer financial aid. The government maintains an online portal providing an overview of available subsidies and how to apply for them.

Subsidies Provided by the Tokyo Government for the Diagnosis and Execution of Seismic Reinforcement and Fireproofing Work

	Wooden structures					Apartments and shelter					Shelter grant
	Diagnosis	Reinforcement design	Refurbishment	Rebuilding	Retirement	Diagnosis	Reinforcement design	Refurbishment	Rebuilding	Advising	
Chiyoda Ward	●		●			●	●	●	●	●	●
Chūō Ward	●	●	●			●	●	●		●	●
Minato Ward	●	●	●	●		●	●	●	Δ	Δ	
Shinjuku Ward	●	●	●			●	●	●		●	●
Bunkyō Ward	●	●	●	●		●	●	●		●	●
Taitō Ward	●	●	●		●	●	●	●		●	
Sumida Ward	●	●	●		●	●	●	●		●	●
Kōtō Ward	●	●	●		Δ	●	●	●		●	
Shinagawa Ward	●	●	●		●	●	●	●		●	●
Meguro Ward	●	●	●		●	●	●	●		●	●
Ōta Ward	●	●	●			●	●	●		●	●
Setagaya Ward	●	●	●	●		●	●	●		●	●
Shibuya Ward	●	●	●			●	●	●			
Nakano Ward	●	●		●		●	Δ	Δ			●
Suginami Ward	●		●		●	●	●	●		●	●
Toshima Ward	●		●			●	●	●		●	●
Kita Ward	●	●	●	●		●	●	●		●	
Arakawa Ward	●	●	●	●		●	●	●		●	●
Itabashi Ward	●	●	●	●	●	●	●	●		●	●
Nerima Ward	●	●	●		●	●	●	●		●	●
Adachi Ward	●	●	●		●	●	●	●			●
Katsushika Ward	●	●	●	●	●	●	●	●		●	●
Edogawa Ward	●	●	●		●	●	●	●		●	

● Subsidies are provided
Δ Partial or limited assistance

Other government initiatives focus on the aftermath of major earthquakes. Traffic regulations, for example, prohibit ordinary vehicles from entering within Tokyo's Seventh Loop Road at such times and also ban them from using roads designated for emergency vehicles. In addition, a 2011 law sets out a long-term programme to inspect and reinforce buildings along emergency-vehicle routes to ensure that roads will not be blocked if they collapse. Another strategy is the construction of more than 200 emergency water supply stations, each catering to an area within a two-kilometre radius, that are responsible for dispensing purified water. Underground water pipes, meanwhile, have been retrofitted with earthquake-resistant joints in an effort to protect them during earthquakes.

Risk: Tsunamis

Although the proximity of offshore subterranean fault lines makes the threat from subsea earthquakes very real, the city is to a great extent sheltered from tsunamis by Tokyo Bay, which has a narrow mouth opening only to the southwest. Simulations conclude that even in a worst-case scenario, inundation should be contained to a relatively small 4.8-square-kilometre area within Greater Tokyo. In addition, the fact that any wave is likely to take at least two hours and 20 minutes to arrive leaves authorities plenty of time to warn of incoming danger.

To protect against tsunamis and tidal surges, Tokyo Bay has been equipped with a network of seawalls and floodgates. Seawalls are built between 4.5 and 8 metres above low tide levels. Floodgates protect canals and mouths of rivers and are remotely operated by a system designed for redundancy (in both its communications network and command-and-control functions) to ensure coordinated operation. This anti-tsunami infrastructure is maintained and upgraded on an ongoing basis.

'Soft' Resilience

Creating sophisticated hardware can do much to help avert disasters, but it is not a panacea. For one, climate change is making extreme weather events more common. In addition, as more new infrastructure is created, local residents become complacent about the risks. Authorities therefore have focused increasingly in recent years on creating 'soft' infrastructure that educates the public about imminent danger.

In 2007, Japan's Fire and Disaster Management Agency (FDMA) introduced the US$1 billion J-Alert early warning system – a satellite-based communications network designed for near-instantaneous and automatic transmission of information about a variety of approaching threats, from natural disasters to incoming missile attacks.

Seismic events are probably the most obvious threat addressed by J-Alert warnings. A network of over 4,000 seismographs located around the country detects tremors and calculates earthquake epicentres. For events with a magnitude greater than 5 on the Japan seismic scale (about 6.0 on the Richter scale), messages are sent out via cellphones, loudspeakers, and conventional media to those in affected areas. J-Alert can warn Tokyo residents of an impending earthquake as much as two minutes before destructive shaking arrives (60 seconds in the case of the 2011 Great East Japan Earthquake). Private early warning systems, such as those created by Japan Railways and gas utility companies, serve similar purposes.

The levels of awareness called upon by J-Alert warnings are divided into five categories.

- **Level 1:** Increase preparedness for potential disasters.
- **Level 2:** Confirm evacuation routes using hazard maps; confirm that preparations are in place for evacuation.
- **Level 3:** Begin evacuating the elderly and others requiring care – those for whom evacuation will take extra time. Others begin preparations for evacuation.
- **Level 4:** Total evacuation of all residents in subject areas.
- **Level 5:** Danger is such that safe evacuation may not be possible. Take appropriate action to preserve life.

For water-related danger, the J-Alert system provides data such as the location and amount of rainfall forecast, as well as which areas along specific rivers are at risk of flooding. Equipment in individual retarding basins warns users about impending local flooding, while basin overflow conditions are also monitored by real-time closed-circuit TV, together with water-level and flow-rate sensors.

Chapter 2: Social and Ritual Resilience

While Tokyo's proactive approach to creating disaster-resistant infrastructure has been vital to its emergence as a resilient metropolis, the city's vast network of sophisticated engineering can sometimes obscure the impact of another equally important factor: the gradual evolution of a social and cultural framework that incentivises residents to cooperate for their mutual benefit.

Japan's long tradition of collaborative working and thinking has its roots in local community structures and traditions that remain as relevant today (albeit in different ways) as they were when they emerged centuries ago. In modern Tokyo they serve not only to protect communities in the event of a natural disaster, but also provide a degree of consensus – often lacking in the West – for undertaking the huge financial investments required to keep the city safe.

The genesis of this consensus-driven mind-set is found in the ancient insular village units known as *shuraku shakai*. So old they predate capitalism in Japan, shuraku shakai consist of different-sized agricultural units belonging to each community. These social groups, together with neighbourhood associations known as *chonaikai* that go with them, have long functioned as both promoters and guardians of the local population. Shinto, which held sway for centuries as Japan's dominant religion, was observed through festivals organised by the chonaikai. These festivals, called *matsuri*, also functioned to draw communities together, providing opportunities to determine and confirm their welfare and growth. Matsuri, therefore, were not mere celebrations: they also served as a means to position religion or the local temple at the centre of the community and recognise a hierarchy established in various ways, such as the extent of monetary contribution.

Every community in Japan celebrates multiple matsuri through the year, with the core festivals usually built around agricultural events such as harvest or planting. In addition to the religious element (often unnoticed today), matsuri involve processions, entertainment, and food stalls – all serving to promote the greater societal group and reinforce community connections. In a sense, matsuri are rather like Thanksgiving or Christmas in the way they reinforce family and community ties.

Nada no Kenka Matsuri, Hyogo Prefecture. (Wikipedia\Sailko)

Each chonaikai has a defined role and is organised by variety of committees representing a range of interests. Elderly groups, for example, handle the celebratory elements, women's groups provide support for the matsuri, youth groups are usually in charge of related portable shrines, and disaster-prevention groups make sure the neighbourhood is on its toes regarding safety and disaster prevention, not only during festivals, but at all times.

An example of the role disaster-prevention groups play in ensuring community safety can be seen in the autumn and winter evening practice in which members walk through the community clapping together sticks and calling out '*hinoyojin*' (beware of fires) as a reminder to residents. These community volunteers are also first responders for fires and other emergencies.

Regular chonaikai meetings are used to promote community awareness and members' knowledge of the neighbourhood, as well as to educate and promote the importance of being part of the whole – both the neighbourhood and its surrounding community – thereby creating social capital that is effective in ensuring the safety of the community in both ordinary and extraordinary times. In more traditional towns, regular house-to-house visits by local police mean they are aware of details such as who lives where and the size of each household.

Japan's famous volunteer fire brigades, known as *shobodan*, are another component of neighbourhood resilience. Found in every municipality, they number about 880,000 people across the country, with members spanning the gamut of occupations and age groups. They are responsible not only for fighting fires, but also for promoting awareness of all types of local hazards and acting as local leaders for disaster prevention generally.

The important role played by the shobodan in the creation of some well-known projects built by Japan's leading developers is another example of the interconnectedness of Japan's traditional and modern worlds. The redevelopment of Roppongi Hills by Mori Building Company, for example, features a chonaikai composed of Roppongi Hills locals that organises a multitude of matsuri in the surrounding area. The shobodan for Roppongi Hills helps maintain the peace during these events and is so proactive that it has been recognised with awards among Tokyo shobodan for its firefighting skills and preparedness.

Studies have found that the more committed and entrenched the chonaikai and shobodan are, the more resilient their neighbourhoods become. Further, the entrenchment and success of the chonaikai are in turn tied to the success and fervour of local matsuri. A 2010 report published by Kyoto University, for example, found that in the town of Kishiwada, famed for its Danjiri Matsuri Festival, high levels of commitment and participation by locals had created greater social capital and awareness of disaster prevention. The study also found that matsuri served to create unusually strong social bonds among the local population, promoting lasting relationships of trust and self-reliance.

Kishiwada Danjiri Matsuri Festival in Osaka Prefecture. (Wikipedia\Kounosu)

A separate study by the university found that the shobodan's day-to-day activities not only reinforce resilience and disaster prevention at the neighbourhood level, but also play a key role in maintaining safety by organising matsuri. Although primarily established as firefighting organisations, therefore, the shobodan actually play a variety of complementary roles, instilling a spirit of local self-reliance that contributes to disaster-prevention activities related to earthquake and water disasters.

A further benefit of the shobodan is that local infrastructure used by these ritual bodies can also be pressed into service for the purposes of disaster relief. Ritual storehouses, for example, function as neighbourhood evacuation centres and provide storage for first-aid equipment and other supplies, while open spaces used for ritual purposes can also play a role in relief operations.

In their different ways, therefore, the ancient institutions of chonaikai and shobodan, along with the areawide reinforcement of the community through the matsuri, create a tripartite relationship comprising rituals, social capital, and disaster risk reduction that form a backbone of resilience running through all of Japanese society. The more recent engineering accomplishments resulting from massive investment in disaster-prevention infrastructure may have a higher profile, but they are no more important than these ancient institutions in the role they play in protecting Japanese society from the threat of natural catastrophe.

Official Initiatives

A number of government programmes complement grassroots community efforts as embodied in the chonaikai and matsuri by educating the public more directly about how to respond to different types of threats at a local community level. The result is an often-bewildering number of disaster training and evacuation drills held across Japan throughout the year. Disaster Prevention Day, for example, held each September 1, is designated nationally as a day dedicated to public drills and educational exercises.

Volunteer fire companies and citizen disaster response teams conduct regular local events, including training in such diverse subjects as disaster evacuation, helping the elderly and disabled, providing disaster prevention information, first aid, disaster-prevention patrol and inspection, and a range of other 'disaster measures,' including firefighting techniques, rescue practices, food and water distribution, and even public relations campaigns.

For flood preparation specifically, a succession of drills, workshops, and proactive events are held across the country each May at the start of the rainy season, targeting especially residents of river basins.

Disaster education pamphlet.

Similar events are held in June, dedicated to providing advice on landslide safety. In addition, August – a time when water use is at its highest – has both a 'water week' from August 1 to 7 and 'water day' on August 1. Disaster prevention activities shift to avalanches in December.

The government has taken a similar approach to earthquake preparation. In 2008, the Committee of Tokyo Residents for Promoting an Earthquake Proof Society was founded with the aim of promoting earthquake-proof buildings. The committee created an alliance of schools, hospitals, department stores, hotels, real estate associations, and other public and government bodies tasked with working together to promote earthquake protection. Disaster prevention weeks have been designated in both September and January (the anniversary of the 1995 Hanshin Earthquake), during which campaigns are held throughout Greater Tokyo to promote an earthquake-proof society.

The Plan for Promoting the Creation of Resilient Cities (*Bosai Toshi Zukuri Suishin Keikaku*), meanwhile, offers advice and help in assessing houses and, if necessary, reinforcing them against earthquakes. There are also guidelines for securing furniture and appliances inside homes, installing fire extinguishers and earthquake-detecting circuit breakers, preparing appropriate stockpiles of food and necessities, and creating a personalised evacuation map identifying (among other things) the location of neighbourhood evacuation centres.

Tokyo's education programmes are not only diverse in terms of subject matter, but also exhaustively comprehensive, featuring vast amounts of electronic and live-event material. The 2001 revisions to the Flood Prevention Act, for example, set out detailed provisions requiring local governments to create disaster management plans for districts most at risk of flooding. Rules are so granular that they stipulate even the methods and language to be used when broadcasting flood warnings and describing evacuation sites. Similar rules set standards for evacuation plans for specific types of facilities such as underground malls, the creation of QR codes and apps that provide direct access to water-risk and flood-hazard maps identifying in real time which areas are unsafe, and also evacuation routes and shelter locations.

The city has nominated about 3,000 schools, community centres, and other public facilities to serve as evacuation centres in an effort to avoid massive numbers of stranded workers or shoppers attempting to return to their homes in the immediate aftermath of a disaster. For the same reason, businesses in the city are required to maintain on site a supply of three days of drinking water, food, and other necessities to cater to stranded employees. Experience has shown that such systematic planning has been instrumental in accelerating evacuation of affected areas when flooding is imminent.

EARTHQUAKE PROOF COMPLIANCE MARK

In April 2012, as a way to reassure residents, the government of Tokyo established the Tokyo Earthquake Proof Mark Display System, indicating the earthquake-proof safety level of individual structures in the city. Marks are displayed at building entrances.

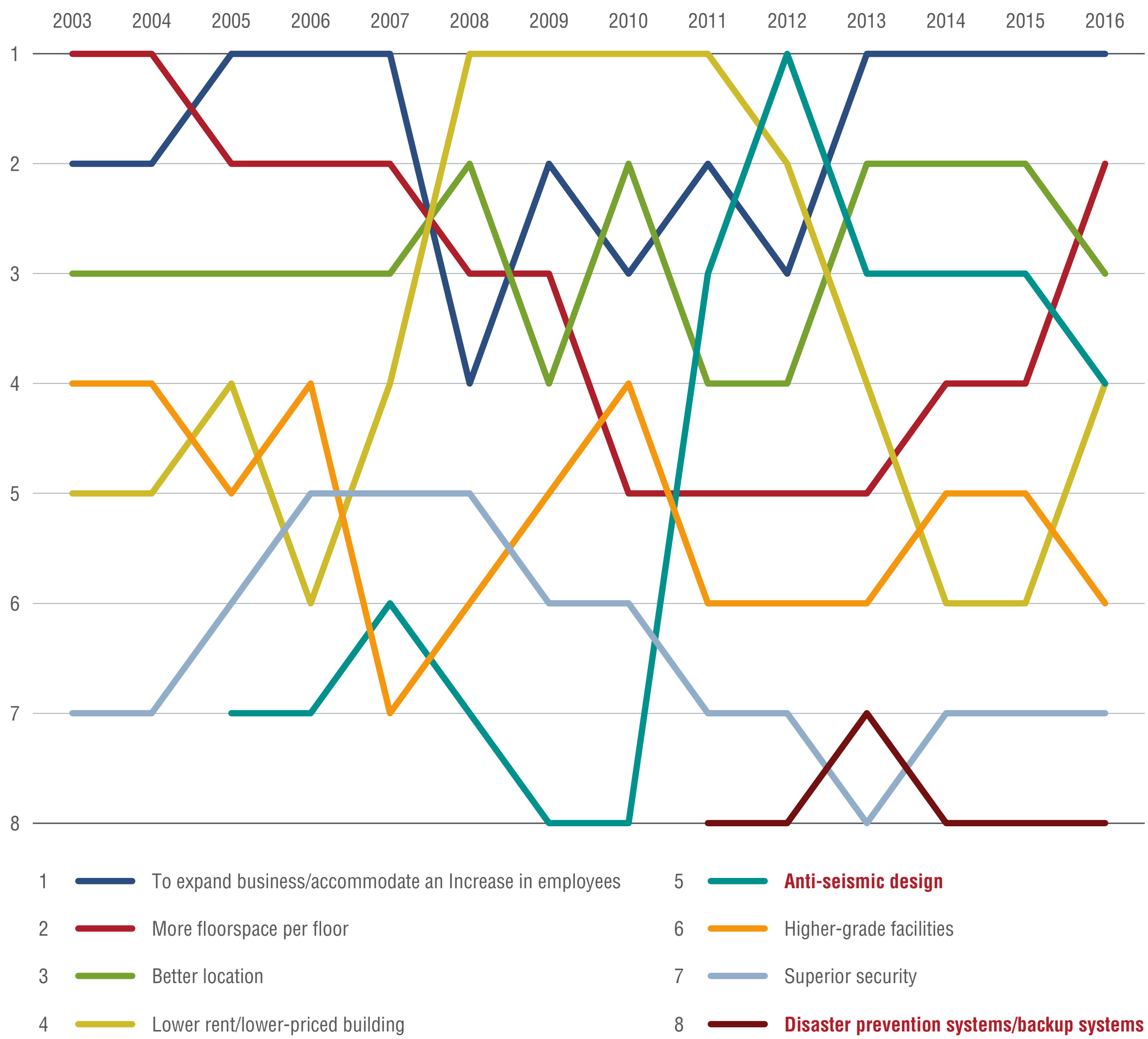
Chapter 3: Developing for Resilience

Because Tokyo has been razed and rebuilt so many times, both investors and landlords are acutely aware of the need for resilient urban design. In the 20th century alone, two cataclysmic events struck the city: in 1923, the Great Kanto Earthquake and its ensuing tsunami and fires destroyed more than half of Tokyo's brick buildings, and shortly thereafter, World War II ushered in a new wave of destruction, this time from the air.

As a result, Tokyo's building design and engineering standards are among the strictest in the world, mitigating risk from a long list of threats including earthquakes, fires, tsunamis, floods, and typhoons. Regulations aim not only to protect the city against the direct impact of these disasters, but also to ensure that it recovers quickly.

Building out this level of resilience does not come cheap. But with occupants of Tokyo's best buildings (and especially foreign tenants) now prizing both seismic functionality and disaster management performance, landlords have found that resilient buildings command significantly higher rents. The trend picked up more momentum following the Great East Japan Earthquake in 2011. Today, therefore, all top-rated buildings in the central five wards of the city cut no corners in implementing state-of-the-art facilities that generally exceed already-high official standards.

Reason for New Lease Plans – Changes in Ranking



Source: Mori Building.

Because Japan's construction industry is dominated by a handful of large players, expertise in earthquake resilience is concentrated at the top of the market, with the flagship projects of major developers regarded as showcases of resilient design. This chapter looks at a number of such projects and their relationship with the neighbourhoods in which they are located.

Asia Pacific Office Leasing Prices, January 2021

	Rent US$ per square metre net
Hong Kong	242.1
Tokyo	179.4
Beijing	115.2
Seoul	105.9
Osaka	103.2
Singapore	100.1
Shanghai	89.4
Taipei	76.1
Ho Chi Minh City	61.4
Shenzhen	61.2
Guangzhou	52.7
Hanoi	41.6
Manila	37.6
Jakarta	34.1
Kuala Lumpur	26.2

Source: Savills.

Mitsubishi Estate Group in the Marunouchi CBD

Mitsubishi Estate Group has long been a key player in the development of the Marunouchi, Otemachi, and Yurakucho areas, the city's primary central business district (CBD), where it manages about 30 buildings. In terms of earthquake resistance, its newer high-rise projects, such as the flagship 37-storey Marunouchi Building, exceed seismic performance levels set by Japan's Building Standards Act by about 50 percent. Its older buildings – those built before the latest seismic design code update in 1981 – have been retrofitted to comply with code.

But the developer is not focused only on its own buildings. With a view to maximising resilience across the entire area, Mitsubishi Estate has created what it calls a 'business continuity district' (BCD) in Marunouchi, the idea being to coordinate with community members and local infrastructure suppliers to create a self-contained bubble that allows the neighbourhood to continue to function even if utilities and communications links are cut during a disaster.

One way to do this is by installing in-building dual-fuel (i.e., natural gas and oil) cogeneration (co-gen) systems, usually in the basements of flagship buildings. Initially conceived as part of a citywide distributed energy system to alleviate demand surges during peak summer periods, these co-gen systems have been repurposed to offer power redundancy on a local basis. While they are unable to serve the neighbourhood in its entirety, coverage is sufficient to allow many businesses to continue to operate if the city grid is disabled. Some buildings also allow individual tenants to install their own parallel in-building generators, providing yet another layer of energy-supply redundancy.

Otherwise, buildings subject to flooding risk have been retrofitted with flood barriers at exits and entrances. Watertight doors are fitted to machine rooms, and facilities crucial to building power supply have been relocated above ground level. As a further resilience feature, many modern buildings use rainwater/wastewater recycling facilities to supply nonpotable water to flush toilets in the event of an emergency. In some, management has even dug wells to guarantee access to water.

The other key element of the Marunouchi resilience plan involves coordination with community businesses, residents, and local government. Buildings owned by Mitsubishi Estate cooperate closely with nearby buildings on disaster response. In addition, 14 of its buildings in the neighbourhood have been designated as temporary disaster shelters. These are equipped with stockpiles of food, essential supplies, and dedicated communications devices to ensure ongoing contact with government officials. Clinics and pharmacies have also been set up in buildings served by neighbourhood co-gen power plants to ensure ongoing access to medical support.

Apart from collaborating with the community at large, Mitsubishi Estate also works with building tenants to provide a range of training exercises, including evacuation drills and annual fire safety council meetings with the fire department. Training is even provided in foreign languages to cater to increasing numbers of international employees.

Nor are resilience efforts in Marunouchi limited to local buildings: utilities ranging from gas to internet services also aim for in-built redundancy. The local electricity grid, for example, provides redundant transmission infrastructure to ensure ongoing supply via secondary cables or different substations even if primary lines are damaged.

That said, not all of Tokyo's power grids enjoy this level of redundancy. In fact, as a nation, Japan has been slow to move power lines underground. Currently, just 8 percent of cabling in central Tokyo is buried, comparing poorly with London and Paris, where almost all supplies are now subterranean.

In terms of gas supplies, the city is better prepared. Tokyo Gas has split the city's medium- and low-pressure pipeline networks into about 250 separate blocks and installed more than 4,000 sensors on pipeline gas governors throughout Greater Tokyo that can selectively shut down networks in blocks worst affected by a disaster, providing a firewall for each area and minimising the impact of any gas outage. As with local electricity lines, the utility has also created built-in redundancy by laying pipelines in multiple configurations to ensure that if supplies from one route are cut, they can be quickly rerouted through another network. In addition, Tokyo uses intermediate-pressure pipes with seismic functionality that far exceeds that of traditional city gas pipes.

District heating and cooling systems, meanwhile, are routed through earthquake-resistant tunnels installed deep underground to minimise the impact of seismic activity. Redundant supply is again available from a network of distribution pipes between plants. Finally, a dedicated data centre equipped with emergency generators with uninterruptible 72-hour power supply supports the Marunouchi area's fibre-optic network.

Mori Building Company's Roppongi Neighbourhood

Mori Building is Japan's fourth-biggest developer, with most assets located in Tokyo's Minato ward, home to many of the country's large domestic companies and foreign embassies. The company is known for its massive long-term urban regeneration projects, such as Roppongi Hills, that have transformed traditional low-rise residential areas into a denser range of mixed-use, high-rise neighbourhoods.

In Japan, the key to embarking on projects of this type, which usually involve long-term negotiations with local property owners, lies in gaining the trust of residents. The company has been remarkably successful in this, at least partly because pre-existing property owners are allocated new homes in the redeveloped neighbourhood. This allows continuity of the original community and its neighbourhood councils, which in turn enables Mori Building to engage the community through those councils and raise resilience awareness as it integrates residents into their new homes.

This is another example of how Japan's big developers look to embrace the entire local community rather than just their own properties, conceiving projects from inception as places of refuge should disaster strike. Buildings are designed not only to be earthquake resistant, but also to function as a focal point for rescue and recovery efforts and to provide shelter and essential services to residents and workers. To facilitate this, local council members include not only residents of Roppongi Hills, but also its office and retail tenants, making it a project-wide initiative.

The 54-story Mori Tower, the centrepiece of the Roppongi Hills redevelopment, sits at the heart of the developer's resilience strategy. Completed in 2003, it is built to the highest standards of earthquake resistance, with a range of features that go well beyond baseline regulatory standards. In particular, a total of 356 semi-active viscous dampers are installed on different floors around the building core. In addition, it has 192 unbonded braces made of soft (and therefore stretchable) steel to absorb shaking caused by both earthquakes and wind. During the magnitude-9.0 Great East Japan Earthquake in 2011, recordings from seismographs installed in the tower showed that these two technologies reduced the expected degree of building displacement by about half.

The tower also boasts a state-of-the-art elevator system fitted with sensors able to detect the initial signals from long-period earthquakes before they increase in intensity. Elevator cars can then be stopped at the nearest floor, allowing users to exit.

In addition, the developer has incorporated a variety of other seismic technologies in its buildings, including:

- 'Sticky walls' that feature a highly sticky substance injected into the interiors of box-steel plates, enabling them to absorb seismic movements of independent steel panels placed inside building walls.
- Base isolation devices (as described in chapter 1) incorporated into building foundations.
- Brake dampers that use the frictional force of braking materials to convert vibration energy into frictional heat.
- 'Slit wall' vibration-damping panels. These were the first energy-dissipation systems used in Japan, appearing in buildings constructed in the 1970s. Long, narrow breaks in reinforced concrete walls turn them from a solid structure into a series of flexible wall columns, thereby eliminating building resonance caused by earthquakes.
- Tuned mass dampers deployed on building rooftops. The Keyakizaka Complex in Roppongi Hills, for example, uses 3,650 tons of soil deployed in a rooftop garden as a damper. Because the soil and plants are physically separated from the building structure, they can act as a pendulum that absorbs the swaying of the structure.

Mori Building Company – Earthquake Resistance Performance

Building name	Year completed (renovated)	Earthquake resistance performance			Adoption of vibration-control devices	Disaster damage estimation system: e-Daps	Emergency earthquake warning system	ELV long-period earthquake countermeasures [4]	Emergency wells	Other
		Exceeds new standard [1]	Meets new standard [2]	Meets old standard [3]						
GINZA SIX	2017	•			•		•	–		Space available for installation of tenant generators; emergency power generator (installed)
Toranomon Hills Mori Tower	2014	•			•	•	•	•	•	Emergency power generator for shared tenant use (installed)
ARK Hills South Tower	2013	•			•		•	•	•	Emergency power generator for shared tenant use (installed)
ARK Hills Sengokuyama Mori Tower	2012	•			•	•	•	•	•	Emergency power generators for business continuity
ARK Hills Front Tower	2011	•			•		•	•	•	Space available for installation of tenant generators
Hirakawacho Mori Tower	2009	•			•	•	•	–	•	Space available for installation of tenant generators
Holland Hills Mori Tower	2004	•			•		•	–	•	Space available for installation of tenant generators
Roppongi Hills Mori Tower	2003	•			•	•	•	•	•	Power supplied by specially designated power supply business facility
The Prudential Tower	2002	•			•		•	•		Space available for installation of tenant generators
Atago Green Hills Mori Tower	2001 (2007)	•			•	•	•	•	•	Emergency power generator for shared tenant use (installed)
Roppongi Hills Gate Tower	2001	•			•		•	•		
Akasaka Tameike Tower	2000	•			•		•	–	•	Space available for installation of tenant generators
Koraku Mori Building	2000	•			•		•	•	•	Space available for installation of tenant generators
ARK Mori Building	1986 (2005)	•			•	•	•	•	•	Space available for installation of tenant generators
Roppongi First Building	1993		•				•	–		Space available for installation of tenant generators
Toranomon 37 Mori Building	1981 (1999)		•				•	–	•	
Toranomon 36 Mori Building	1981 (2004, 2012)		•				•	–		Emergency power generator for shared tenant use (installed)
Toranomon 35 Mori Building	1981 (2001, 2011)		•					–		Emergency power generator for shared tenant use (installed)
Toranomon 33 Mori Building	1977 (1999, 2007)		•					–		
Toranomon 30 Mori Building	1975 (2007)		•					–		
Roppongi Hills North Tower	1971 (2004)		•				•	•		
Toranomon 15 Mori Building	1969 (2010)		• [5]					–		

Source: Mori Building.

[1] Earthquake resistance performance that exceeds the standards determined by the current Building Standards Law.
[2] Earthquake resistance performance that meets the standards determined by the current Building Standards Law.
[3] Earthquake resistance performance that meets the standards prior to revision of the Building Standards Law in 1981.
[4] ELV long-period earthquake countermeasures are installed according to the length of elevator shaft (measures to prevent ropes becoming caught when resonance occurs).
[5] Renovation for earthquake maintenance.

In general, public infrastructure resilience in Japan relies heavily on networked computer systems to communicate and analyse data, and the same approach has been adopted by private developers. In Mori Building's case, software known as the Earthquake Damage Presumption System (e-Daps) can instantaneously analyse structural damage after an earthquake via a network of in-building seismographs. The system measures the extent of structural acceleration and potential deformation, assesses damage, informs disaster response centres, and prioritises emergency response actions. In addition, e-Daps can issue warnings to tenants when long-period earthquake vibrations are expected. Even a one- or two-minute head start can be enough to save lives.

Providing redundant energy supply to the surrounding neighbourhood is another important feature of Mori Tower's resilience. While Roppongi Hills has long featured dedicated backup power facilities for Mori Building's own tenants, the dedicated co-gen plant in the Mori Tower basement is able to provide both heat and power to a total of 755,000 square metres of floor area throughout the neighbourhood via a gas-powered turbine connected to the local grid. The fact that power demand in the area is fairly evenly split between business and residential buildings ensures that plant output remains consistent throughout the day, increasing operational efficiency by about 10 percent compared with energy drawn from the city grid.

Multiple levels of redundancy help ensure continuity of power supply. Gas was chosen as the optimal fuel because the city's piped grid is significantly more resistant to seismic movement than the equivalent electric power infrastructure. Supplies come via a looped and networked supply so that if the main gas line is cut during an earthquake, alternative lines can still supply fuel to the co-gen plant. Beyond that, Mori Tower is connected to backup power sources from the city's electricity grid and is further supported by an on-site kerosene-fired emergency generator, with on-site storage tanks providing 72 hours' worth of fuel.

This multiple-redundancy system helped ensure that the Mori Tower plant could continue to supply adequate power to the local neighbourhood during several months of supply disruptions in the aftermath of the 2011 Great East Japan Earthquake, which had knocked out a number of power stations along the eastern seaboard. Indeed, it was the success of the Mori facility during that episode that inspired other developers to install their own co-gen plants elsewhere in the city.

Mori Building has also taken other steps to boost resilience in Roppongi Hills. The area's traditional narrow roads have been widened to provide better access for emergency vehicles. In addition, construction of multiple high-rise buildings in place of the existing low-rise sprawl has increased density to the point that multiple new green open spaces could be created, providing a refuge from both the intensity of the city in normal times and from the hazards of an earthquake in the event of a disaster. Some 100,000 meals stored on site in Roppongi Hills allow residents to shelter in place for at least three days.

Following the 2011 earthquake, Mori Building took stock of its experiences to refine its resilience strategies. Further backup energy infrastructure was added, an agreement was signed with the local government allowing several neighbourhood buildings to be used as official disaster shelters, a stockpile of mountain bikes was established for post-disaster use, and a partnership with broadcaster NHK was formed to provide earthquake announcements within company buildings. Meanwhile, staff training continues to be a priority: drills are held twice a year, with more frequent training provided to disaster-response personnel.

Mitsui Fudosan Co.'s Nihonbashi Revitalisation

Mitsui Fudosan is another long-established developer with large real estate holdings concentrated in the central Tokyo district where the company has its roots – in this case, the ultra-prime Nihonbashi business district. Its two-decade-long project to upgrade and modernise its Nihonbashi properties provides another example of how Japan's largest developers function as catalysts for ongoing efforts to boost regeneration and resilience.

Reinventing inner-city neighbourhoods in this way is no small feat. While smart-city projects are common in the context of greenfield or campus projects, implementing them in a dense urban context already integrated into the city fabric is far more challenging, especially in historic districts such as Nihonbashi. By forging momentum that other property owners (and also the city government) can follow, these large-scale inner-city revitalisation projects help create smart and sustainable neighbourhoods that contribute in their own right to the city's overall resilience.

One lynchpin of Mitsui Fudosan's 15- to 20-city-block Nihonbashi revitalisation plan is the Nihonbashi Muromachi Mitsui Tower. The mixed-use, 26-storey office block is built to the highest standards of construction and technology expected of Tokyo's grade-S properties (i.e., one step above grade A). In terms of resilience, it incorporates the latest earthquake-resistant features such as structural-control oil dampers, reducing building sway by about 50 percent.

In addition, the building's electronic evaluation system quickly calculates earthquake damage based on measurements of distortion angles, shortening the time needed to assess potential impairment of the building structure to just 10 minutes, compared with a multiday period previously. Emergency accommodations and supplies to cater to stranded workers are also in place.

Another aspect that reflects the building's community-oriented focus is the creation of the Nihonbashi Smart Energy Project in collaboration with Tokyo Gas. Following the lead of similar projects as described above, Mitsui Fudosan has installed a large-scale gas co-gen energy plant in the Mitsui Tower basement capable of providing power and heat for 1 million square metres of floor space in 20 or more neighbouring buildings. It is currently the largest such facility in the city. In an emergency, the co-gen system can meet up to 50 percent of peak-level energy demand, sufficient to allow businesses to continue to operate during a blackout. The plant also maintains and operates a dual-fuel (oil and gas) emergency generator in the same location, as well as local power distribution facilities such as transmission lines and substations, creating what is effectively a private power grid for the local community. More co-gen plants are now being built in various parts of the city.

However, while such facilities have proved themselves an effective source of local backup power in an emergency, the number of operational facilities of this type in Tokyo represents only the tip of the iceberg when set against the city's total power demand. Given that the expense of construction and operation is likely to be prohibitive for smaller local developers whose pockets are not as deep as those of Mitsui Fudosan and its peers, the reality is that co-gen plants probably will never become mainstream facilities unless the government opts to subsidise installation.

SUSTAINABILITY IN TOKYO BUILDINGS

Local regulations make Tokyo's buildings among the most resilient in the world in terms of earthquake mitigation. But what about resilience in terms of sustainability?

Since 2002, all newly constructed residential buildings in the city have been subject to comprehensive sustainability standards set out by the Tokyo Metropolitan Government's Green Building Program (GBP). Previously, only buildings with floor space of at least 10,000 square metres were included. That size requirement was halved in 2010, when the programme was also broadened to include commercial buildings.

The GBP evaluates buildings on the extent to which they preserve the environment, are energy and resource efficient, and mitigate the heat-island effect. Graded scores (on a scale of 1 to 3) are posted on the Metropolitan Government website and in some cases must be actively disclosed by owners (for instance, in sales materials for residential developments and in counterparty sales documents for commercial projects). The programme therefore provides scope to boost values of high-scoring buildings. (For details, see **Tokyo Green Building Program**.)

In addition to the GBP programme, the Tokyo Metropolitan Government has launched a pioneering urban cap-and-trade scheme aimed at large-scale commercial facilities – the first of its kind in both Japan and the world. By limiting total building emissions and allowing companies that outperform their target to sell the savings as a credit, the scheme in effect taxes carbon dioxide emissions across Tokyo's largest companies. According to the city's *Tokyo Green Building Report 2015*, the cap-and-trade programme has helped facilitate a 23 percent reduction in CO_2 emissions since inception.

Another city government initiative involves a carbon reduction reporting scheme that covers some 630,000 small and medium-sized facilities not included in the cap-and-trade programme. Under this scheme, owners of eligible facilities are required to submit reports on emissions and energy use, receiving a rating from the government in return. Depending on their standing, they can then tap a range of low-energy strategies and subsidies for energy-saving equipment. This not only provides small and medium-sized businesses a path to energy sustainability, but also allows the government to gather important data on businesses that together contribute over 60 percent of citywide emissions.

While regulatory requirements have in this way helped create a template within which developers and landlords in the city can (and must) work to achieve sustainability goals, there is also a sense – especially at the higher end of the market – that developers act as good corporate citizens, setting high standards for others to follow. As a result, sustainability policies adopted by individual landlords are often significantly tougher than those set by regulations. In 2019, for example, Mitsubishi Estate adopted medium- to long-term greenhouse gas emissions targets that aim to cut emissions from its buildings by 35 percent by 2030 and 87 percent by 2050.

While the willingness to embrace such policies may be due in part to increasing demand from both tenants and investors for buildings that feature high environmental, social, and governance (ESG) standards, it also reflects, once again, an intangible cultural dynamic in which different parts of society pull together for the collective good.

WELLBEING AND HEALTH

Though they earn high marks in terms of environmental sustainability, Tokyo buildings are less impressive in their commitment to wellness.

Historically, workplace culture in Japan has required employees to work long hours in offices that are often old-fashioned in terms of fit-out. More recently, however, and partly as a result of increased focus on work/life balance among Japan's younger demographic, new trends have emerged. According to the Global Wellness Summit, Japan is now the second-largest national workplace wellness market behind the United States, with spending of about $3.9 billion annually.

That said, much of this money is directed towards physical health and fitness rather than other types of wellness initiatives. A 2016 report by office design solutions company Steelcase, for example, revealed that only 5 percent of respondents in Japan viewed their workspaces as 'stimulating or innovative'.

Still, international approaches to workspace design are now seeping into the market, with local offices of multinational companies introducing more modern, collaborative office spaces and generally promoting awareness of how work environments can affect individual productivity. Further progress is likely as companies embrace new approaches to workplace use and layout in the wake of the COVID-19 pandemic.

The country's gradual shift towards health and wellbeing in the workplace is reflected by the recent emergence of international wellness standards in Japanese buildings, with the first WELL certification being awarded just over three years ago. The Obayashi Corporation – whose Techno-Station project earned Gold certification – along with Shimizu Corporation (one of Japan's top five contractors) have led the way in transforming Japan's workplace wellbeing initiatives.

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