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The Yamanote Loop: Unifying Rail Transportation and Disaster Resilience in Tokyo

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by

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This capstone is dedicated to my family, Grammy, Mom, Dad, Kathy, Alyx, and Sam, for their unwavering love and support, and to my beloved grandfather, who is dearly missed.

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ABSTRACT

As climate change and population growth persist, and as the world rapidly urbanizes, major cities across the globe will face unprecedented strains. The risk of devastating impact from natural disasters increases in areas with a growing concentration of people. Megacities in Asia are the most at-risk of natural disasters, given their geographic location and high population density. With the highest projected population growth in the world, Asian cities must quickly expand and adapt their existing infrastructure to accommodate the transforming global conditions.

A remarkable anomaly amongst Asian megacities, Tokyo, Japan is effectively adapting to its earthquake-prone environment. Within the last century, Japan has implemented seismically reinforced buildings and educational resources for earthquake preparedness. Amongst other technological innovations, investments in railway transportation have permitted major cities like Tokyo to expand and adjust according to its changing needs. The Yamanote Line is the primary commuter rail line in Tokyo. Its antecedent originated in 1885 and has since undergone significant changes to evolve into the highly sophisticated system it is today.

By examining the evolvement of the Yamanote line from its conception and into the 21st century, this study explores the correlation between local rail transportation networks and their city's resilience to natural disasters. A descriptive analysis aligned with four constructs of transportation resilience—robustness, redundancy, resourcefulness, and rapidity—observes instances in which the Yamanote line potentially strengthens Tokyo's comprehensive disaster preparedness. The following study intentionally circumvents normative-prescriptive conclusions and focuses primarily on the impact of transformations of railway transportation on its broader urban context over time respective to disaster resilience and with consideration of other relative factors.

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“We cannot stop natural disasters, but we can arm ourselves with knowledge: so many lives wouldn't have to be lost if there was enough disaster preparedness."

Petra Nemcova, founder of the Happy Hearts Fund

1. INTRODUCTION: An Urgent Need for Resilient Urbanism in Asia and Beyond

1.1 An Evolving World

Over the last century, the world has witnessed an exponential growth in population, which has contributed to the expansion of cities and urban living. According to a United Nations report, over half of the world population lives in urban areas, and by 2050 that proportion is expected to evolve into over two-thirds of the population living in cities.[1] By that time in Asia, home to some of the most massive cities in terms of population and land coverage, city populations are projected to increase by a tremendous ninety percent.[1] As the global climate continues to deteriorate, Asian megacities, in particular, are expected to feel the worst repercussions. The risk of impact from natural disasters is higher in areas where the urban infrastructure is weak and emergency preparedness is limited. Weak economies force impoverished communities to inhabit areas vulnerable to sea-level rise.[2] Absent of such conditions, numerous Asian cities are nevertheless more vulnerable to natural disasters than cities in other world regions. Their geographic locations put them at higher risk of destruction from volcanic eruptions, frequent earthquakes, tropical storms, and tsunamis. These factors already make cities like Jakarta, Mumbai, and Manila dangerous places to be in the event of a disaster, and the risks are likely only going to increase as rapid population growth propels the environmental crisis and as weather patterns become increasingly volatile.

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[1] "World Urbanization Prospects - Population Division." United Nations. Accessed April 30, 2018. https://esa.un.org/unpd/wup/.

[2] "Asian Cities More Vulnerable to Natural Disasters." The Guardian. October 21, 2010. Accessed June 16, 2019. https://www.theguardian.com/global-development/2010/oct/21/asian-cities-natural-disasters-risk.

1.2 Tokyo: A City Responding to Risk

Figure 1.1 Pacific Ring of Fire[3]

One of the more at-risk cities of natural disaster in the world is Tokyo, Japan. Tokyo is the largest urban area in the world, covering 12,000 square miles over 500 connected settlements.[4] It is massive in both its size and its metro population of over 13 million,[5] which continues to increase despite a decline in population nationwide. It also exists in one of the most vulnerable countries to disaster based on its geographic location in the Ring of Fire (Figure 1.1), a horseshoe-shaped string of volcanoes and seismic activity that traces the edges of the Pacific Ocean and accounts for roughly 90% of all earthquakes.[6] However, advances in technology, education, and transportation in Japan have aided the adaption of Tokyo's infrastructure to these risks and led Japan to become the most earthquake-prepared country in

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[3] "Online Activities: Weather Watch." Scholastic.com. Accessed April 12, 2020. http://teacher.scholastic.com/activities/wwatch/volcanoes/explore.htm.

[4]"Cities Cover More of Earth than Realized." LiveScience. Accessed June 15, 2019. https://www.livescience.com/6893-cities-cover-earth-realized.html.

[5]"Tokyo Population 2019." Tokyo Population 2019 (Demographics, Maps, Graphs). Accessed June 1, [4] 2019. http://worldpopulationreview.com/world-cities/tokyo-population/.

[6]National Geographic Society. "Plate Tectonics and the Ring of Fire." National Geographic Society, October 9, 2012. https://www.nationalgeographic.org/article/plate-tectonics-ring-fire/?utm_source=BibblioRCM_Row.

the world.[7] In fact, despite the higher likelihood and frequency of natural disasters in Japan, a person is seventeen times more likely to be killed by natural disasters in the Philippines than it is in Japan.[2]

Much of the disparity between nearly earthquake-resistant Tokyo and other Asian megacities derives from long-standing investments made in both the national and local rail transportation systems. Rail is the primary means of public transport in Tokyo, and approximately 2.4 million people commute to Tokyo via rail every day.[4] Hence, it is imperative that these rail systems prioritize public safety by performing exceptionally in events leading up to, during, and following a natural disaster. It is also necessary that the spatial organization of such routes, stations, and their surrounding areas withstand shocks and facilitate safety and connectivity. Through historical investigation, spatial mapping, and direct observation of the Yamanote loop line, this descriptive case study explores how the progression in the spatial organization and advancement in the railways serving the Greater Tokyo Area has adequately supported resilience efforts and how such efforts may serve as an exemplar for other cities and nations facing comparable threats.

[7] Dayman, Lucy. "8 Ways Japan Prepares for Earthquakes." Culture Trip. January 10, 2018. Accessed June 1, 2019. https://theculturetrip.com/asia/japan/articles/8-ways-japan-prepares-for-earthquakes/.

“No matter where you’re located - a large city or a rural town - ‘infrastructure’ is fundamental to your daily life. Whether you’re walking on a dirt road or driving on a highway, networks of transportation connect you to others, to commerce, to work. When those systems falter, everyday life suffers.”

Tariq Taherbhai, Senior Director, Aon Infrastructure Solutions

2. TRANSPORTATION: A Critical Infrastructure

Transportation is considered a critical infrastructure since its disruption can leave devastating social and economic wounds in a city or even a nation. According to a team of industry experts from the Boston Consulting Group, the Future of Construction, and the University of Waterloo, for a transport system to be considered resilient, it must exhibit four essential dimensions (Table 2.1): robustness, redundancy, resourcefulness, and rapidity. Robustness is “the capacity to withstand shocks without losing functionality,” redundancy defined as “whether infrastructure networks have alternative routes available,” resourcefulness as, “the ability to restore functionality,” and rapidity as, “when infrastructure is. . . designed and operated in a way that can quickly be restored after lost functionality, [then] disruption effects will be limited.”[8] Though not entirely immune to environmental impact, rail networks typically stand as the most resilient of all transportation systems thanks to their mesh-like structure; the typical timeframe for repair is a matter of months compared to several years to restore ports.[8]

[8]"Transportation and Disasters." The Geography of Transport Systems. May 26, 2019. Accessed August 3, 2019. https://transportgeography.org/?page_id=6295.

Table 2.1 Breakdown of resilience parameters for transport systems[9]

Robustness	Status of assets Capacity to withstand climatologic variations Physical interdependency with other systems Geographical interdependency (size of the system, number of independent systems) Logical interdependency (number of independent systems)
Redundancy	Local workarounds or substitutions Availability and capability of alternative routes Availability and capability of alternative modalities
Resourcefulness	Availability of emergency funding Availability of expertise and manpower Availability of equipment and materials for restoration and repair
Rapidity	System downtime Restoration time

[9] "Transportation and Disasters." The Geography of Transport Systems. May 26, 2019. Accessed August 3, 2019. https://transportgeography.org/?page_id=6295. (Adapted by Author)

“Tokyo was an origami city folded over and over until something was made of virtually nothing.”

Christopher Barzak, *The Love We Share Without Knowing*

3. TOKYO: An Introduction

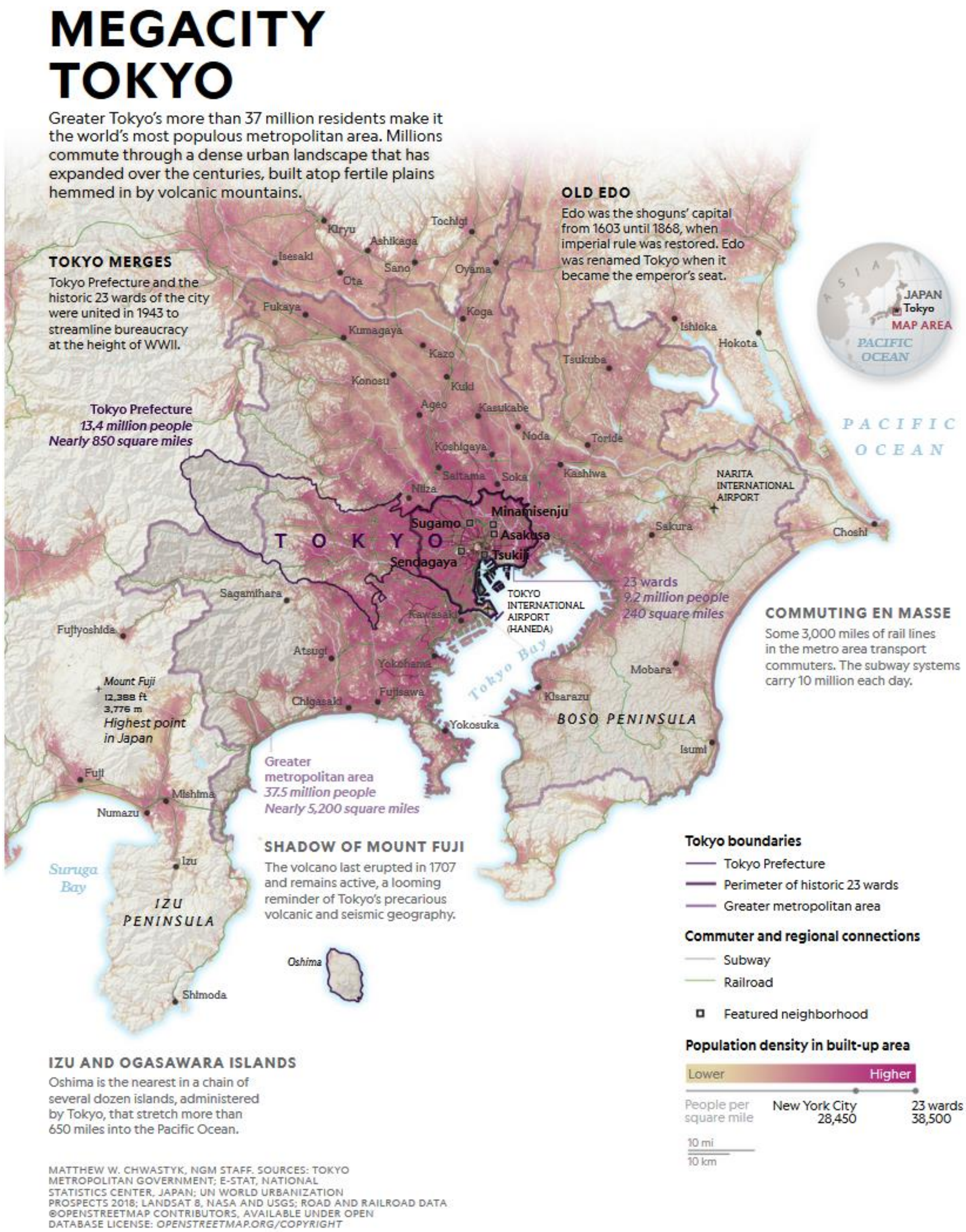

Figure 3.1 Tokyo: A Megacity[10]

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[10] Shea, Neil, and David Guttenfelder. "Tokyo Became a Megacity by Reinventing Itself." National Geographic, March 14, 2019. https://www.nationalgeographic.com/magazine/2019/04/how-tokyo-japan-became-megacity-by-rebuilding-after-earthquake-war/.

The extensive growth and modification of Tokyo (Figure 3.1), one of the largest urban centers in the world, is most prevalent in the last century. Urbanization, modernization, rapid industrialization, and Westernization have radically transformed Japanese cities following the Meiji restoration in 1868.[11] Likewise, Tokyo has adapted in response to threats of natural or human-made disasters, such as the major fire in 1872 that destroyed nearly 3,000 homes in the Ginza area[12] or the 1923 Great Kanto Earthquake[13] that devastated Tokyo, the nearby port city of Yokohama, and the surrounding prefectures.

Japan ranks as the fifth most earthquake-prone country in the world.[14] Its exposure to frequent natural disasters coupled with the massive population of 38 million people in the Greater Tokyo Area[15] makes Tokyo one of the most vulnerable cities in the world in the presence of a disaster. Evidence suggests that as climate change persists, there may be an increase in earthquake frequency over time. Chi-Ching Liu from the Institute of Earth Sciences explains that the, "low-pressure centers of typhoons allow earthquake faults within the crust to move and release accumulated strain."[16] Although climate change cannot cause quakes that would not have otherwise occurred,[16] it does pose the threat of triggering earthquakes much sooner, leaving less time for preparation. As climate change persists, infrastructure in Tokyo will have to prove its earthquake resilience or adapt to the evolving behaviors of the environment.

Fortunately, decades of progress in Tokyo's urban development have established a strong foundation for resilience. Tokyo reigns superior in the education and resources it can provide to its

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[11]"Japan's Modern History: An Outline of the Period: Asia for Educators: Columbia University." Japan's Modern History: An Outline of the Period | Asia for Educators | Columbia University. Accessed April 13, 2020. http://afe.easia.columbia.edu/timelines/japan_modern_timeline.htm.

[12]Vale, Lawrence J., and Thomas J. Campanella. *The Resilient City: How Modern Cities Recover from Disaster*. New York: Oxford University Press, 2005.

[13]The Great Kanto Earthquake of 1923. Accessed April 13, 2020. https://library.brown.edu/cds/kanto/denewa.html.

[14]Nag, Oishimaya Sen. "The World's 10 Most Earthquake Prone Countries." WorldAtlas. WorldAtlas, April 11, 2019. https://www.worldatlas.com/articles/the-world-s-10-most-earthquake-prone-countries.html.

[15]Barrett, Brendan, and Marco Amati. "Five Lessons from Tokyo, a City of 38m People, for Australia, a Nation of 24m." The Conversation, August 29, 2019. https://theconversation.com/five-lessons-from-tokyo-a-city-of-38m-people-for-australia-a-nation-of-24m-78335.

[16]Wu, Floris. "Does Climate Change Really Trigger Earthquakes?" Medium. NU Sci, June 19, 2018. https://nuscimag.com/does-climate-change-really-trigger-earthquakes-41a91477e7fc.

citizens to prepare them for emergencies. Additionally, the highly developed economy of Japan allows for private and public developers to invest in high-quality urban planning efforts. Its transportation infrastructure is extraordinarily advanced and carefully planned. The development includes the advanced local rail system in Tokyo, which serves the staggering 13 million locals in Tokyo city, the 3.7 million daily regional commuters, and the additional 31,000 that commute by shinkansen, or bullet train.[17] According to National Geographic, at least 10 million people use Tokyo's rail network, which is more than the entire population of New York City.[3]

Figure 3.2 Yamanote Line[18]

Of all the available monorails, bullet trains, subways, and expressways in Tokyo, the Yamanote line (Figures 3.2, 3.3) in the center of the city is one of the busiest and most prominent lines in Japan. It

[17]Hirooka, Haruya. The Development of Tokyo's Rail Network. Accessed April 13, 2020. http://www.ejrcf.or.jp/jrtr/jrtr23/F22_Hirooka.html.

[18]Adriana. "The New Yamanote Line Station: Takanawa Gateway." REthink Tokyo - Real Estate Information for Buyers and Investors, January 14, 2019. https://www.rethinktokyo.com/new-yamanote-line-station-takanawa-gateway.

connects all the major stations in the city, including Shinjuku, Shibuya, and Ikebukuro, the three busiest stations in the world. The Yamanote Line's history extends back to 1885.[19] Its ongoing evolution since then serves as a focal point for investigating the efforts made in Japan to accommodate growing populations and to mitigate the corresponding increased risks of prevalent natural disasters.

Figure 3.3 Passengers prepare to board a Yamanote Line train[20]

[19]Shiozaki, Thomas. "The Storied History of the Yamanote Line." All About Japan. Accessed August 11, 2019. https://allabout-japan.com/en/article/2207/.

[20]"Last Train Rides to Be Extended by up to 2 Hours during Olympics : The Asahi Shimbun." The Asahi Shimbun, January 23, 2020. http://www.asahi.com/ajw/articles/AJ202001230043.html.

“City growth has caused climate change, but that growth is also what’s going to get us out of it.”

Matthew Kahn, UCLA economist, *Climatopolis*

4. METHODS: Evaluating the Progress of Resilience in Tokyo's Yamanote Rail Development

According to Robert K. Yin, a case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 13)."[21] In this case study, the phenomenon and context in question is the degree(s) of resilience that the Yamanote line gives to the city and the event of a natural disaster in Tokyo, Japan, respectively.

A case study can fall within several different categories, one of which is a descriptive case study. Yin writes that a descriptive case study is "advantageous when the research goal is to be predictive about certain outcomes (Yin, 6)."[21] This study of the Yamanote line uses both historical development and direct observations to craft a narrative of how transit networks, such as this one, can morph into systems that support the resilience and safety of their broader urban contexts.

In addition to historical data and direct observations, the study uses spatial mapping to identify patterns of development over time. Supporting quantitative data includes referential statistics such as population growth or decline, population density, passenger information, and figures related to operation controls. The parameters of resilience—**robustness, redundancy, resourcefulness,** and **rapidity**—are discovered in varying degrees in the sections to follow. Table 4.1 illustrates the potential representative resilience characteristics found through each method of research.

[21]Yin, Robert K. *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage Publications, 2003.

Table 4.1 Representative Resilience Characteristics Found in Research Approach

	Historic Analysis	Spatial Mapping	Direct Observations
Robustness	Physical state of railway following a disaster	Organization of route over time Organization of tracks following a major disaster	Response to emergencies (if applicable)
Redundancy	Existing alternative means of transport in various time periods	Alternate Routes Nearby Emergency Facilities	Alternate routes Navigability
Resourcefulness	Developments to train car design Technological Innovations Available equipment for restoration Financial investments in railway development Refinement to operation controls	N/A	Available emergency facilities and features Earthquake preparedness educational opportunities
Rapidity	Records of system downtime following a disaster, if available	Restoration time following earthquake impact	Interruptions to functionality (if applicable)

“Growth is inevitable and desirable, but destruction of community character is not. The question is not whether your part of the world is going to change. The question is how.”

Edward T. McMahon, the Urban Land Institute Chair on Sustainable Development and Environmental Policy

5. HISTORIC ARC OF RESILIENCE AND THE YAMANOTE LINE

5.1 Yamanote: The Early Years

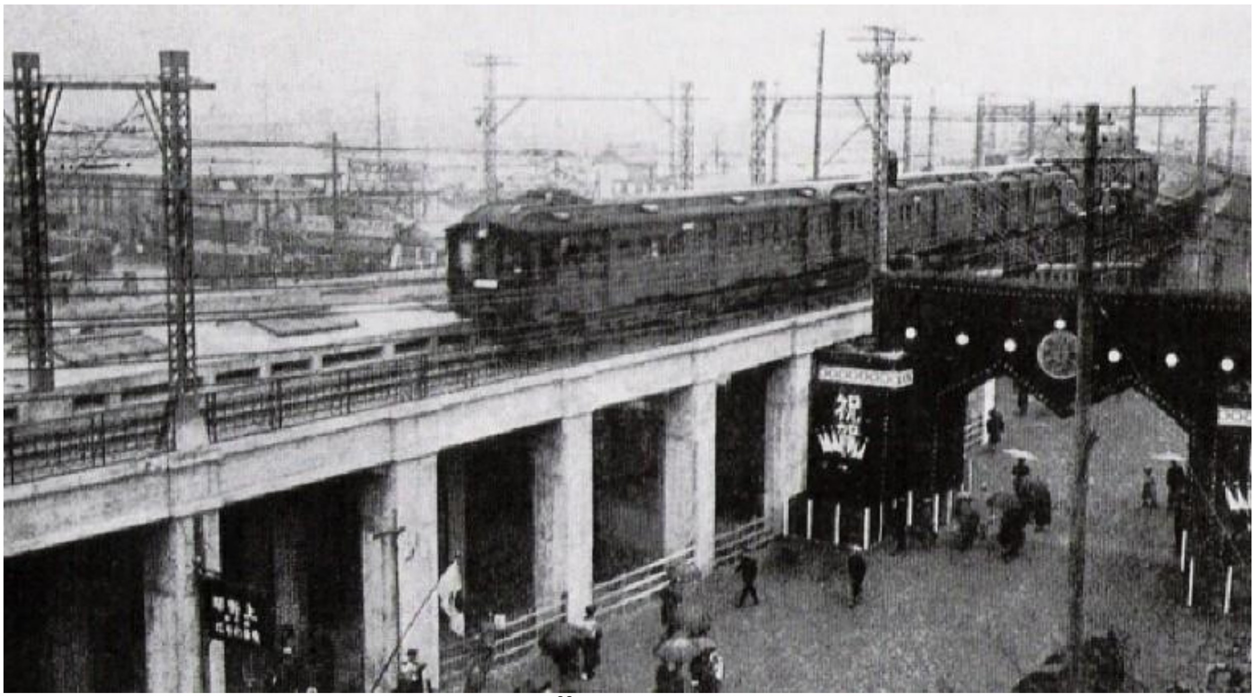

Figure 5.1.1 Yamanote Line predecessor circa 1900[22]

The Yamanote Line is one of the busiest rail passenger lines in Tokyo and in the entire world. According to the East Japan Railway Company, the line sees approximately 3.72 million passengers daily, and equates that to “carrying the entire population of the US state of Oklahoma every single day.”[23] As of March 14, 2020, there are thirty stations along the line, and a full journey around the loop takes about one hour (Figure 5.1.2).

[22]Shiozaki, Thomas. “The Storied History of the Yamanote Line.” All About Japan. Accessed April 12, 2020. https://allabout-japan.com/en/article/2207/.

[23] “Tokyo's Yamanote Line: More Than You Ever Wanted To Know.” DeepJapan. Accessed January 29, 2020. http://www.deepjapan.org/a/4472.

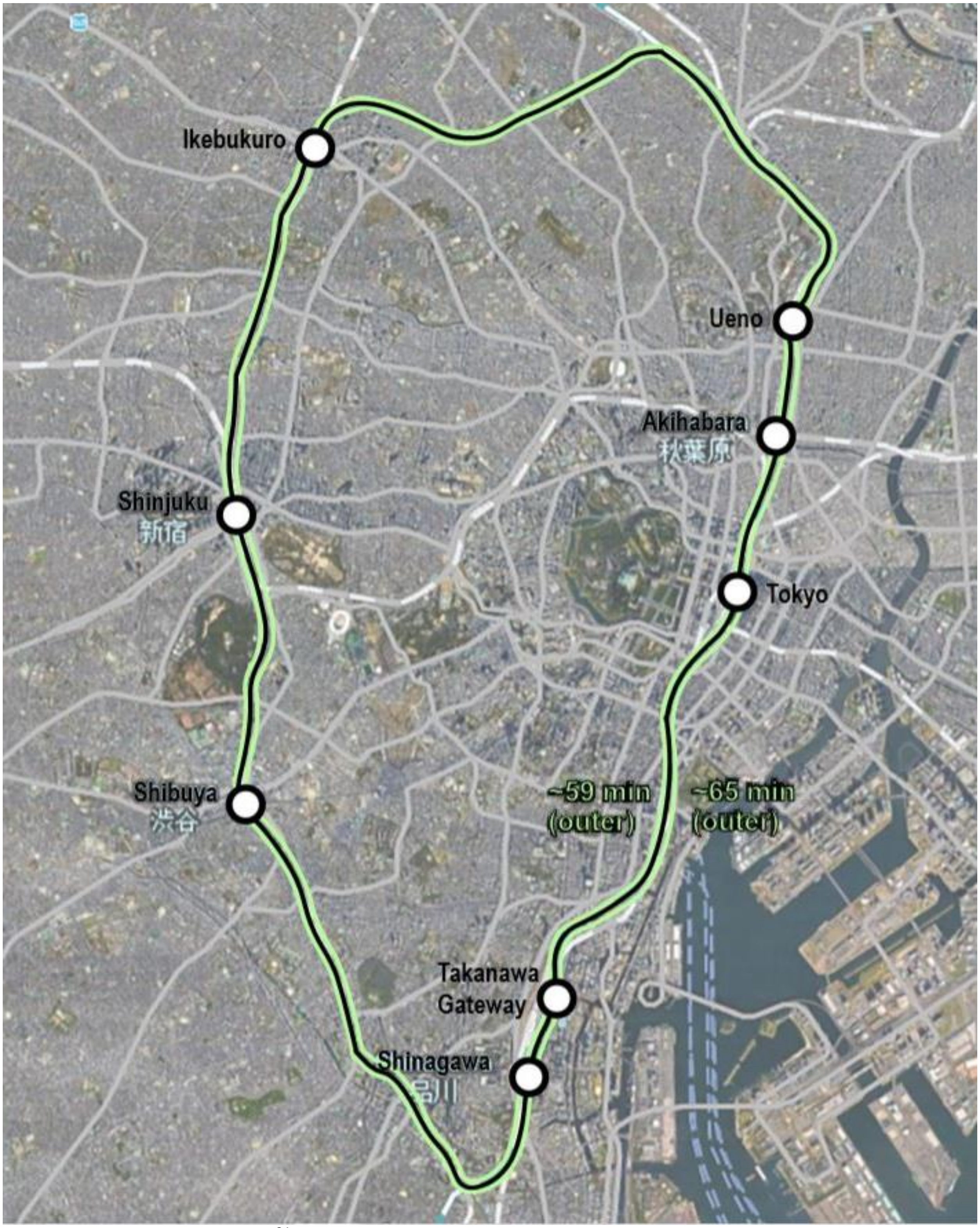

Figure 5.1.2 Yamanote Line map[24]

[24]Author

Despite its enormous presence and vitality to daily life in Tokyo, the Yamanote Line comes from humble beginnings. Its antecedent originates back to 1885 (Figure 5.1.1), less than a decade after the first railway in Japan began operating in 1872.[25] Tokyo had only been the capital of Japan since 1868, the year that marked the end of the 260-year Edo Period and the emergence of the Meiji Restoration.[25] Once reinstated as head of government, the emperor introduced a modernization program to consolidate the new government's authority. The emperor reorganized Japan into the modern 47 prefectures. With the assistance of industrialists and elite technologists, the program connected city centers across Japan to the main cities of Tokyo and Osaka through railroads and telecommunications. Thus, Japan laid the first tracks in 1872 between Tokyo and Yokohama, a modest 29 kilometer stretch of railroad that would eventually evolve into one of the most complex and advanced rail networks in the world. For reference, Table 5.1 displays the total length of Japanese rail networks from 1872 to 1912, illustrating the rapid industrialization of railways in Japan.

Table 5.1.1 Length of Japanese Rail Networks, Kilometers*

Year	Public	Private[a]	Total
1872	29	0	29
1877	105	0	105
1882	185	0	185
1887	393	472	865
1892	886	2,125	3,011
1897	1,065	3,681	4,746
1902	1,974	5,398	7,372
1907	7,152	1,568	8,720
1912	8,396	2,988	11,384

*includes long-distance and local rail and tram networks[26]

[25]"TOKYO'S HISTORY, GEOGRAPHY, AND POPULATION." History of Tokyo - Tokyo Metropolitan Government. Accessed February 12, 2020. https://www.metro.tokyo.lg.jp/ENGLISH/ABOUT/HISTORY/history01.htm#:~:text=.

[26]Tang, John P. "Railroad Expansion and Industrialization: Evidence from Meiji Japan." *The Journal of Economic History* 74, no. 3 (2014): 863–86. https://doi.org/10.1017/s002205071400062x.

The introduction of railroads in Japan sparked rapid industrialization and economic growth. Only four lines in Japan had been established by 1880, but that network quickly expanded to connect almost the entire country by the 1920s.[27] The Japanese government sought improvements in transportation infrastructure to centralize political power, streamline national defense, and promote economic growth in remote areas.[28] To encourage the utilization of regional passenger lines, many stations featured department stores and various attractions at major stations. This contribution to the economic growth meant that extensive freight lines, as well as passenger lines, would be established. One of the earliest freight lines in Japan opened in 1885 and ran between Shinagawa Station and Akabane Station. It was known as the Shinagawa Line until 1909 when it merged with the second freight line to open in Tokyo just five years earlier. The second line connected Tabata Station and Ikebukuro Station, which now facilitates the transportation of nearly one billion passengers per year. Now that the Akabane station is no longer on the line, this merged line is the earliest existing stretch that would eventually belong to the modern-day Yamanote passenger line.

In the decades to follow, rail freight would dominate other forms of domestic transport. At the time of their conception, the city laid tracks for freight lines in areas of Tokyo where they were least likely to interfere with residential and commercial activity. As a result, tracks were directed towards the outer edges of the city. Inevitably, economic growth in the infant capital of a rapidly advancing nation meant substantial population growth. The sprawl in development beyond the existing city center to accommodate such growth eventually extended to areas where the freight rail network ran. City officials took the initiative to transform several freight lines into passenger lines instead. In 1909, the formerly known Shinagawa Line was renamed "Yamanote" regarding the inland, hillier districts of the city.

The Yamanote Line continued expanding through connections to other passenger and former freight lines. Unfortunately, rail construction slowed in 1923 due to the magnitude 7.9 Great Kanto Earthquake that devastated Tokyo. After two years of reconstruction efforts, the Kanda and Akihabara

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[27]Hays, Jeffrey. "TRAINS IN JAPAN: HISTORY, ORGANIZATION, JR COMPANIES, PROBLEMS AND ACCIDENTS." Facts and Details, October 2012. http://factsanddetails.com/japan/cat23/sub153/item853.html.

[28] Tang, John P. "Railroad Expansion and Industrialization: Evidence from Meiji Japan." *The Journal of Economic History* 74, no. 3 (2014): 863–86. https://doi.org/10.1017/s002205071400062x.

stations were linked together, which meant that Tokyo and Ueno Stations were now connected, making the Yamanote Line a fully closed loop line for the first time (Figure 5.1.3). Table 5.1.2 shows the summarized evidence of resilience displayed by the Yamanote Line from the years 1885 to 1922.

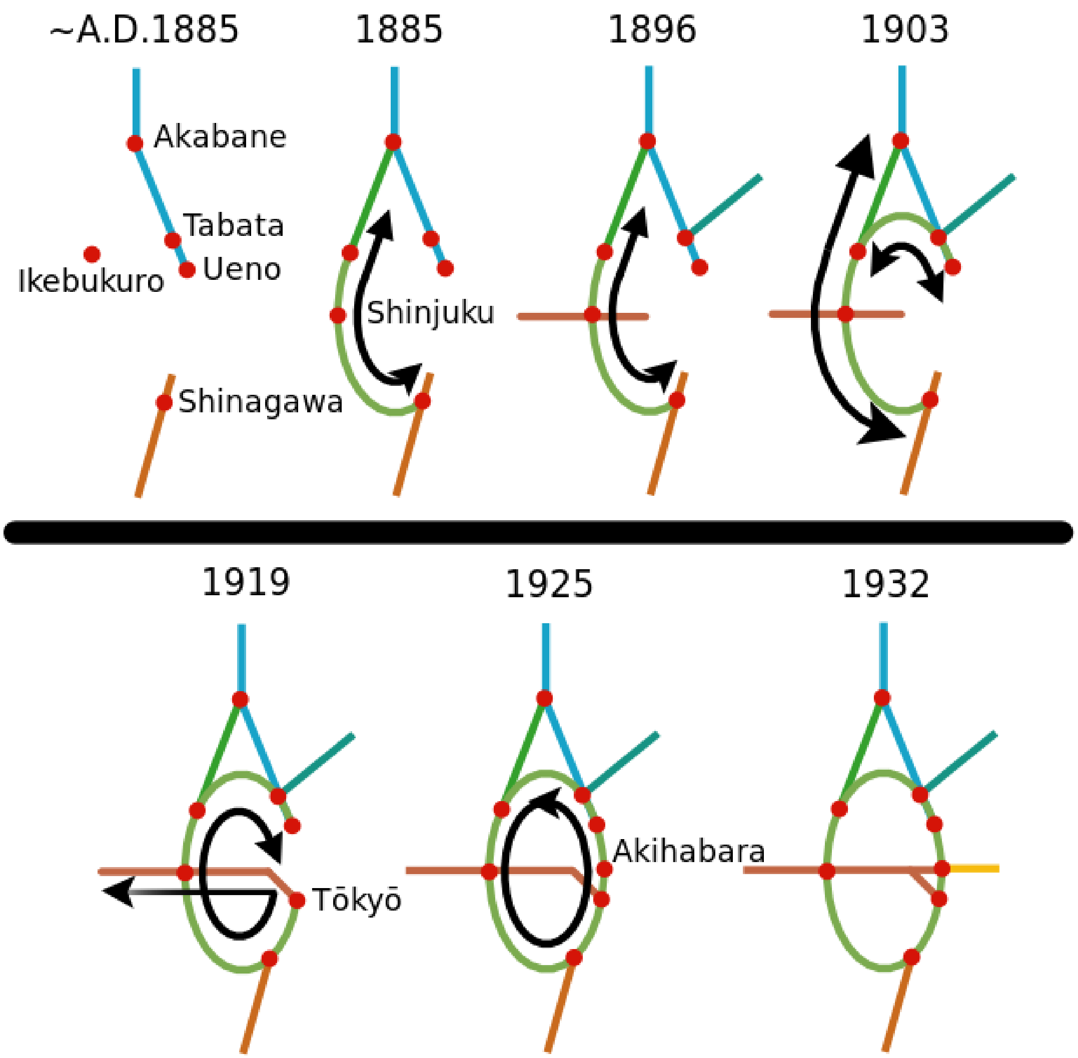

Figure 5.1.3 Transformation of Yamanote Line route[29]

[29]Pendleton, Mark, and Jamie Coates. "Thinking from the Yamanote: Space, Place and Mobility in Tokyo's Past and Present." Taylor & Francis. University of Sheffield. Accessed March 27, 2020. https://www.tandfonline.com/doi/full/10.1080/09555803.2017.1353532.

Table 5.1.2 Evidence of Resilience Constructs I (1885 – 1922)

Resilience Constructs	**Summary of Evidence**
Robustness	Tracks were able to withstand earthquake and fire; only endured a brief pause in development in the two years to follow
Redundancy	Not demonstrated. Alternative railway routes not developed by this time, only roads
Resourcefulness	Rapid industrialization Conversion of existing freight lines into passenger lines preserves repurposes existing tracks
Rapidity	Rapidity demonstrated in rapid initial development, but no records available to indicate rapidity in the return of function from system downtime

“Designing a dream city is easy; rebuilding a living one takes imagination.”

Jane Jacobs, *Downtown is for People*

5.2 1923 and the Aftermath

On the morning of September 1st, 1923, just as people were gathering for lunch, disaster struck in Tokyo. At a measure of 8.2 on the Richter scale, the Great Kanto Earthquake devastated the city and left surrounding areas like Yokohama in ruins.[30] The earthquake and resulting fire claimed the lives of over 130,000 people[30] and destroyed nearly 33 million square meters of urban settlement.[31] For at least one week following the disaster, the Japanese armed forces repaired land-based infrastructure, which included the removal of over 3,000 damaged rail cars and trams that had derailed in Tokyo.[31] Eighty-five kilometers of rail tracks were rebuilt, and 27 temporary bridges were constructed across Tokyo's rivers to alleviate the strain on transportation and to facilitate the transportation of relief supplies.[31]

As indicated by the extensive relief efforts on transportation infrastructure, the rail network in Tokyo during this time was unable to resist a disaster of this magnitude. The damage to so many rail cars and such extensive distance of tracks suggests a lack of robustness. The need for temporary bridges as alternative means of transport indicates a lack of redundancy; the inability for functionality to return to previously laid tracks for such a lengthy timeframe indicates poor resourcefulness, and the prolonged system downtime and restoration efforts indicate poor rapidity. Despite this immense tragedy, the city was able to honor the many lives lost eventually. Learning from this event and rebuilding Tokyo would prevent future earthquakes from causing such catastrophic damage in the future.

Arguably, the damage from the Great Kanto Earthquake was a stimulus to the growth of the railway system as much as it was, paradoxically, a hindrance to the system as well. The 1923 Imperial Reconstruction Plan enacted by the city of Tokyo called for the widening of streets and improved

[30]The Great Kanto Earthquake of 1923. Accessed March 23, 2020. https://library.brown.edu/cds/kanto/denewa.html.

[31]The Aftermath - The Great Kantō Earthquake.com. Accessed March 23, 2020. http://www.greatkantoearthquake.com/aftermath.html.

connections to surrounding areas.[32] One significant instance of this plan is the creation of a broad avenue extending east from Tokyo Station and terminating at the moat surrounding the Imperial Palace,[32] an intervention whose effect on the Yamanote and daily life in Tokyo is felt long after its conception.

Figure 5.2.1 Shinjuku Station 1925[33]

The most notable effect of reconstruction efforts on the Yamanote ignited by the earthquake is the creation of public plazas and adjacent commercial space along the line (Figure 5.2.1). Through the Imperial Capital Reconstruction Project, detailed plans were created for new plazas outside several stations along the Yamanote, including Shinbashi, Shibuya and Ikebukuro, and the reconstruction period would last through 1930.[33] To make this possible, urban planners advocated for restrictions on the sale and division of land to private entities. Instead, the land was to be either owned publicly or sold to railway

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[32]Ling, Lo Cheuk. "Tokyo (1889-1923) I Land Readjustment after the Great Kanto Earthquake." Asian Cities Research, December 13, 2017. https://fac.arch.hku.hk/asian-cities-research/tokyo-1889-1923-l-land-readjustment-after-the-great-kanto-earthquake/.

[33]Ling, Lo Cheuk. "Tokyo (1923-1930) I The Great Kanto Earthquake and Railway Development." Asian Cities Research, December 13, 2017. https://fac.arch.hku.hk/asian-cities-research/tokyo-1923-1930-i-the-great-kanto-earthquake-and-railway-developoment/.

companies with an interest in creating public plazas.[33] The intention for the creation of public spaces and their adjacent commercial areas was to meet the rising traffic demands by attracting people to the railway.[33] The attention brought towards spatial development around train stations also ignited diligent reimagination of the tracks themselves as a parallel project of its own. One such change was the connection between Kanda and Akihabara in 1925, which linked Tokyo and Ueno Stations, completing the full circle of the Yamanote Line. Undoubtedly, the Great Kanto Earthquake had devastating effects on the city of Tokyo and its surroundings, but the careful planning and diligent reconstruction that followed will pave the way for a more disaster-resistant city to exist going forward and to subsequently demonstrate how even low-technology solutions can curate resilience.

Figure 5.2.2 (left) Aerial view of Tokyo after airstrikes,[34] Figure 5.2.3 (right) Tokyo residents who lost their homes to the airstrikes[34]

Not long after the earthquake struck in 1923, World War II ravaged Japan. This event would prompt the second time that Tokyo would rebuild itself in the last century. The bombing of Tokyo (Figure 5.2.2), which took place on the night of March 9, 1942, is "often cited as one of the most destructive acts of war in history."[35] An estimated 80,000 to 100,000 people lost their lives, and approximately one million people were left homeless (Figure 5.2.3).[35] Several stations along the Yamanote were destroyed,

[34]Rich, Motoko. "The Man Who Won't Let the World Forget the Firebombing of Tokyo." The New York Times. The New York Times, March 9, 2020. https://www.nytimes.com/2020/03/09/magazine/the-man-who-wont-let-the-world-forget-the-firebombing-of-tokyo.html.

[35]Grant, R.G. "Bombing of Tokyo." Encyclopædia Britannica. Encyclopædia Britannica, inc., March 2, 2020. https://www.britannica.com/event/Bombing-of-Tokyo.

including Komagome, Takadanobaba, Shinagawa, and Tokyo Station. Ueno Station, which was rebuilt following the 1923 earthquake, survived the bombings and stands today as one of the busiest stations along this line and in the world.[36] Figure 5.2.4 illustrates the population growth over time, beginning in the Edo period, compared to the measured devastated areas following the Great Kanto Earthquake and the World War II bombing. Table 5.2.1 shows the summarized evidence of resilience displayed by the Yamanote Line from the years 1923 to 1945.

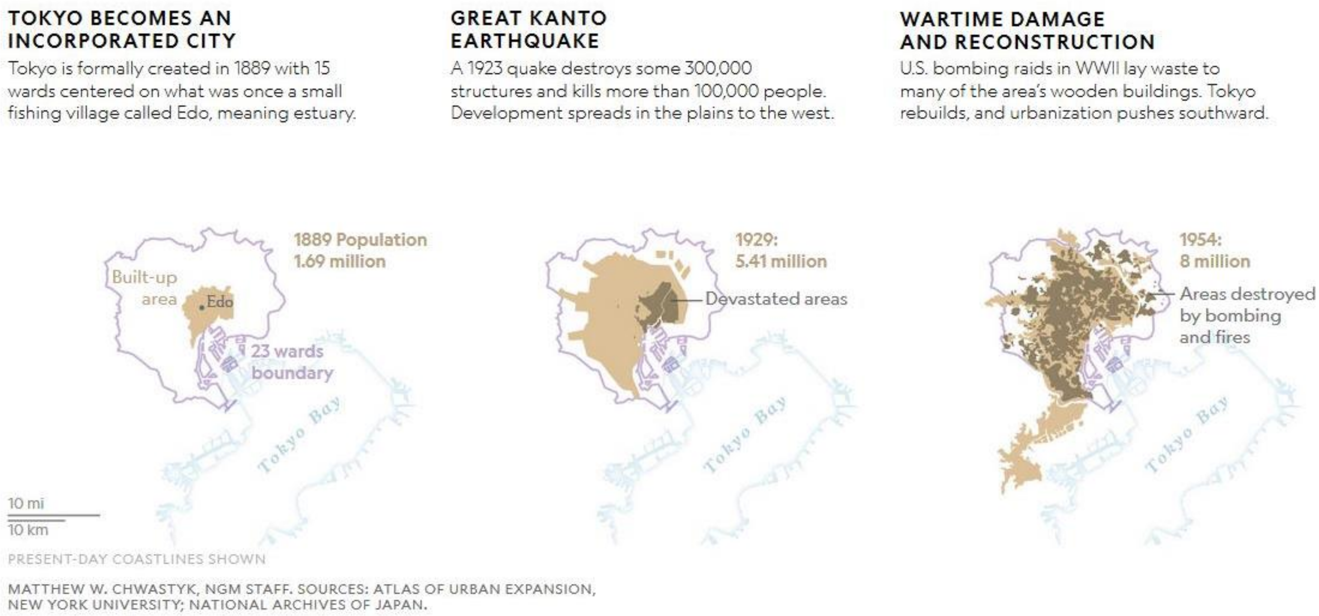

Figure 5.2.4 A History of Disaster and Recovery[37]

[36]"Tokyo's Yamanote Line: More Than You Ever Wanted To Know." DeepJapan. Accessed January 29, 2020. http://www.deepjapan.org/a/4472.

[37]Shea, Neil, and David Guttenfelder. "Tokyo Became a Megacity by Reinventing Itself." National Geographic, March 14, 2019. https://www.nationalgeographic.com/magazine/2019/04/how-tokyo-japan-became-megacity-by-rebuilding-after-earthquake-war/.

Table 5.2.1 Evidence of Resilience Constructs II (1923 – 1945)

Resilience Constructs	**Summary of Evidence**
Robustness	Tracks were able to withstand earthquake and fire; only endured a brief pause in development in the two years to follow
Redundancy	Not demonstrated. The lack of alternate routes presented itself when roads were destroyed or unusable following the disasters. No alternative commuter railway routes existed during this time; majority of railways were freight lines used to bring in emergent supplies.
Resourcefulness	Completion of full loop in 1925 makes sensible use of existing tracks Planning of space adjacent to stations as public plazas will prove as useful placemaking devices long into the future, attracting people to the commuter railways, and therefore an industry worthy of innovative development
Rapidity	Rail constructions slowed following the 1923 earthquake but resumed within two years as part of reconstruction efforts. Damage was a stimulus to the growth of railways more than it was a hinderance.

"However, it is according to the dictates of time and fate that we have resolved to pave the way for a grand peace for all the generations to come by enduring the unendurable and suffering what is not sufferable."

Emperor Hirohito, announcing Japan's acceptance of the Potsdam Declaration, Jewel Voice Broadcast, 1945

5.3 A New Era

The second half of the twentieth century began during a time of devastation and turmoil. Once World War II ended in 1945, the occupation of Japan by the Allied Powers meant a loss of all political and military power from the emperor within just two years and an increasingly unsteady economy.[38] Almost all of Japan's territory acquired after 1894 was lost, and severe damage was left on industries and transportation networks. Something of a miracle, the boost in the economy later arrived predominantly due to the Tokyo Summer Olympics and the introduction of the first shinkansen, or bullet train, in 1964.[38] By the mid-seventies, technological advancements coupled with the oil embargo[39] pushed Japanese industries to expand and develop more refined levels of efficiency.

Tokyo's rail system maturation during this new era is attributable primarily to the encouraged cooperation between public and private sectors to help stimulate the economy. This partnership between public and private entities is why underground rails in Tokyo are typically private, and most above-ground lines like the Yamanote are now public. If it were not for the conspicuous distinction between above and underground lines, the otherwise seamless connection of routes indicates an effective partnership that mutually benefits both passengers and industries.

The Japanese National Railways formerly operated the Yamanote line until it was privatized in 1987.[40] To preserve the public ownership of Tokyo's most famous line, the Yamanote was passed to the Japan Railways Group[40] and has been operated by the JR East regional division ever since.

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[38] "Post War History (since 1945)." Japanese history: Postwar. Accessed March 26, 2020. https://www.japan-guide.com/e/e2124.html.

[39] U.S. Department of State. U.S. Department of State. Accessed March 26, 2020. https://history.state.gov/milestones/1969-1976/oil-embargo.

[40] "Tokyo's Yamanote Line: More Than You Ever Wanted To Know." DeepJapan. Accessed January 29, 2020. http://www.deepjapan.org/a/4472.

Along with this managerial transition came significant measures to improve the design of the cars themselves. JR inherited a large fleet of 103 series cars (Figure 5.3.1) that had been operating since 1963.[3] Although they were still considered reliable vehicles, the maintenance was too expensive and had cost JNR significantly during their ownership. These trains were made of steel and therefore required frequent cosmetic maintenance to prevent rust. The cars also consumed an excessive amount of electricity, and despite more than two decades of refinement of the already highly efficient propulsion systems used in shinkansen throughout the country, the 103 series cars simply could not adopt the technology of their high-speed counterparts.

Figure 5.3.1 103 series Yamanote Train[41]

Work was quickly underway to produce a new model that could eliminate operating costs and enhance longevity. JR began phasing in the new 205 series trains in 1988. The new model, initially designed by its former owner, was produced with stainless steel and therefore weighed 6 tons per car fewer than its predecessor and required less maintenance. The 205 series adopted regenerative braking, which could return energy to the power grid upon stopping at stations, but it continued using the same inefficient resistor-based power controls as the last model.

[41]"Sumida Crossing." JR East Tōkyō Urban Trains. Accessed April 13, 2020. http://www.sumidacrossing.org/Prototype/JREast/JREastTokyoUrbanTrains/.

The series of trains developed during the late 20th century demonstrate resourcefulness through their continuous refinement of the design. However, there are still significant modifications to the train design that need to manifest, in addition to technological innovation and operations enhancement, that will not come until the 21st century approaches. Table 5.3.1 shows the summarized evidence of resilience displayed by the Yamanote Line from the years 1946 to 1999.

Table 5.3.1 Evidence of Resilience Constructs III (1946 – 1999)

Resilience Constructs	**Summary of Evidence**
Robustness	Older train models did not prove robustness since steel material required frequent maintenance. However, the new ownership of JR meant that new, more robust models could quickly phase into service.
Redundancy	No evidence
Resourcefulness	Productive cooperation between public and private railway owners allowed for a more complete system to develop. Without this cooperation, the economic stagnation of the time would have prevented either party from investing the necessary resources needed for a comprehensive system to flourish. The integration of regenerative braking returns energy to the power grid.
Rapidity	No evidence

“The fact that it was the biggest earthquake in Japan’s history reached us. I looked out the window, but pedestrians were going about their errands as before. Everyone’s main concern seemed to be facing rush hour without any public transport.”

Carin Nakanishi, an intern working in a Tokyo office at the time of the Great East Japan Earthquake

5.4 2011 Great East Japan Earthquake

The magnitude-9 earthquake that struck on March 11, 2011 near Tohoku was the most powerful earthquake ever recorded in Japan[42] since the first use of seismic recording devices in 1900.[43] This record-breaking earthquake took place 15.2 miles beneath the surface and 231 miles northeast of Tokyo.[44] The quake was so powerful that it shifted the earth's axis approximately 25cm and moved the main island of Honshu 2.4 meters closer to the United States.[1] Even the subsequent tsunami reached nations as far away as South America nearly 11,00 miles across the Pacific Ocean.[3] An estimated 20,000 people were killed or missing, and another 500,000 people faced evacuation.[45]

The Great East Japan earthquake in is easily one of the most tragic natural disasters to happen in modern times. Though modifications to nuclear power plant generators could have prevented the subsequent nuclear meltdown in Fukushima,[46] destruction of this magnitude is extremely difficult to prevent. Remarkably, the advanced railway system by this time was incredibly successful in preventing even a single death or injury. For the first time in history, it is obvious how gradual modifications to transport infrastructure can avert an additional unnecessary tragedy amid disaster.

At the time of the quake, there were 49 shinkansen running throughout Japan.[47] The Urgent Earthquake Detection and Alarm System (UrEDAS) installed in 97 locations throughout the country gave

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[42]Hurst, Daniel. "'This Is Not a 'What If' Story': Tokyo Braces for the Earthquake of a Century." The Guardian. Guardian News and Media, June 12, 2019. https://www.theguardian.com/cities/2019/jun/12/this-is-not-a-what-if-story-tokyo-braces-for-the-earthquake-of-a-century.

[43]Reid, Kathryn. "2011 Japan Earthquake and Tsunami: Facts, FAQs, and How to Help." World Vision, February 29, 2020. https://www.worldvision.org/disaster-relief-news-stories/2011-japan-earthquake-and-tsunami-facts.

[44]Israel, Brett. "Deadly Japan Earthquake Upgraded to 9.0-Magnitude." LiveScience. Purch, March 14, 2011. https://www.livescience.com/13232-japan-earthquake-upgrade-magnitude-9.html.

[45]"2011 Japan Earthquake - Tsunami Fast Facts." CNN. Cable News Network, February 25, 2020. https://www.cnn.com/2013/07/17/world/asia/japan-earthquake---tsunami-fast-facts/index.html.

[46]Acton, James M., and Mark Hibbs. "Why Fukushima Was Preventable." Carnegie Endowment for International Peace. Accessed April 4, 2020. https://carnegieendowment.org/2012/03/06/why-fukushima-was-preventable-pub-47361.

[47]"Alcatel-Lucent." Railway Technology. Accessed March 23, 2020. https://www.railway-technology.com/videos/2337628655001/20/.

JR East enough time to bring all 49 shinkansen to an emergency stop before the impact.[6] Though there were 2,590 incidences of displaced tracks, only one bullet train running under test without passengers derailed that day.[6] Even 2,590 incidents of damage is minimal when considering that Japan's railway system covers 27,500 kilometers[6] and carries 40 million passengers daily. Mitsubishi Research Institute senior consultant and railway development expert Takeshi Fukayama remarked, "As the railway system is large and complex, the speed of restoration was incredible . . . the railway operators and other people concerned made the recovery a first-priority project."[6]

At 231 miles south of Tohoku, Tokyo experienced only minor repercussions. Still, footage reveals the remarkable swaying of Tokyo skyscrapers designed with earthquake-resistant seismic dampers, indicating the sheer power of this historic earthquake. Interruptions to Tokyo's local rail network only resulted from electrical shortages, but many trains were intentionally stopped for inspection and maintenance.[6] Business operations on all lines could recommence the following day. Table 5.4.1 shows the summarized evidence of resilience displayed by the Yamanote Line from the years 2000 to 2011.

Table 5.4.1 Evidence of Resilience Constructs IIII (2000 – 2011)

Resilience Constructs	**Summary of Evidence**
Robustness	The UrEDAS system gave enough warning to prevent impact on shinkansen trains. The UrEDAS system is the same system used for JR East local lines like the Yamanote, which means that the Yamanote would likely have withstood the impact if the epicenter of the earthquake had been closer to Tokyo.
Redundancy	Many passengers in Tokyo were unable to return home the day of the earthquake since precautionary manual inspections meant that the trains were down anyway. However, by 2011, the Tokyo railway system is developed enough that alternative routes would have been available if manual inspections had not temporarily decommissioned them.
Resourcefulness	Use of same technology as high-powered shinkansen in local lines like Yamanote
Rapidity	Not evident – earthquake was too far to directly affect the Yamanote line, and manual inspections left the trains down for approximately 24 hours. It is not clear if the inspections were enforced on every line in Tokyo, or if any lines other than the Yamanote returned to full function on the same day as the earthquake.

“Victory is the beautiful, bright-colored flower. Transport is the stem without which it could never have blossomed.”

Winston Churchill

6. TECHNOLOGICAL ADVANCEMENTS

At over 200 miles away from the epicenter of the Tohoku earthquake, Tokyo was spared from any significant damage. The same technology used that protected passengers on the shinkansen on that day in 2011 is the same technology integrated into local passenger lines like the Yamanote line since its ownership lies in the hands of JR East. However, had this event happened even a few decades earlier, it may have been an entirely different story.

Along with the Urgent Earthquake Detection and Alarm System, critical managerial changes came about once Japan Railways claimed ownership of the Yamanote in the late 20th century. JR integrated the operation controls system,[48] which ensures that the railway network operates as efficiently as possible. The Tokyo Operation Control Center monitors about 8,000 trips per day on 24 local rail lines, including the Yamanote Line.[48] The center uses a system called ATOS, the Autonomous decentralized Transport Operation control System, allowing dispatchers the remote manual control of trains.[48] Dispatchers can monitor delays and intentionally stagger trains to ensure equal distribution, offsetting the buildup of passengers waiting at station platforms.[48] The Control Center also practices rapid response time when an emergency button on a train or at a station has been pressed.[48] Dispatchers can monitor the situation and quickly decide if all or partial operations should suspend on the rest of the line. The ability to respond quickly in the event of "mini-shocks" is a reliable indicator of the center's preparedness for an event of a greater magnitude, which is clear evidence of rapidity and robustness regarding transport resilience. Additionally, only two staff members are needed to monitor the Yamanote line at a time.[48] Even though the Yamanote is arguably the busiest local rail line in the world, its function as a loop establishes an efficiency that eliminates the need for additional staff. In the event of an emergency, staff from other departments are available to assist,[48] which makes the Yamanote an incredibly resourceful system.

[48] "Japan Rail Journal," n.d.

Figure 6.1 an E235 series Yamanote Line train in operation[49]

In addition to operations improvements, the Tokyo Metro has ensured that all rails have been seismically reinforced (Figure 6.2),[50] and seismometers will prompt all trains to stop in response to strong shaking.[50] The emergency stops prevent trains from derailing, thereby significantly reducing the likelihood of injuries and fatalities. This technology is an excellent example of robustness and resourcefulness in resilient transportation systems. It means that high-speed trains can withstand earthquakes by anticipating their arrival thanks to this advanced equipment.

Although Japan's economy has been slow over the last two decades,[51] refinements to the rail system and the Yamanote Line especially have continued. The E231-500 train model was introduced to the line in the early 2000s,[4] and a new model was introduced in response to the 2011 Tohoku earthquake. The new E235 Series (Figure 6.1) was first introduced in 2015[4] and have been gradually

[49] Author

[50]Hurst, Daniel. "'This Is Not a 'What If' Story': Tokyo Braces for the Earthquake of a Century." The Guardian. Guardian News and Media, June 12, 2019. https://www.theguardian.com/cities/2019/jun/12/this-is-not-a-what-if-story-tokyo-braces-for-the-earthquake-of-a-century.

[51]Reid, Kathryn. "2011 Japan Earthquake and Tsunami: Facts, FAQs, and How to Help." World Vision, February 29, 2020. https://www.worldvision.org/disaster-relief-news-stories/2011-japan-earthquake-and-tsunami-facts.

phased in to replace all the E231 series in time for the Tokyo Olympics initially scheduled in 2020. Trains that are phased out of significant commuter lines like the Yamanote are recycled to suburban lines, another indicator of the system's resourcefulness. Table 6.1 shows the summarized evidence of resilience displayed by the Yamanote Line from the years 2012 to 2015.

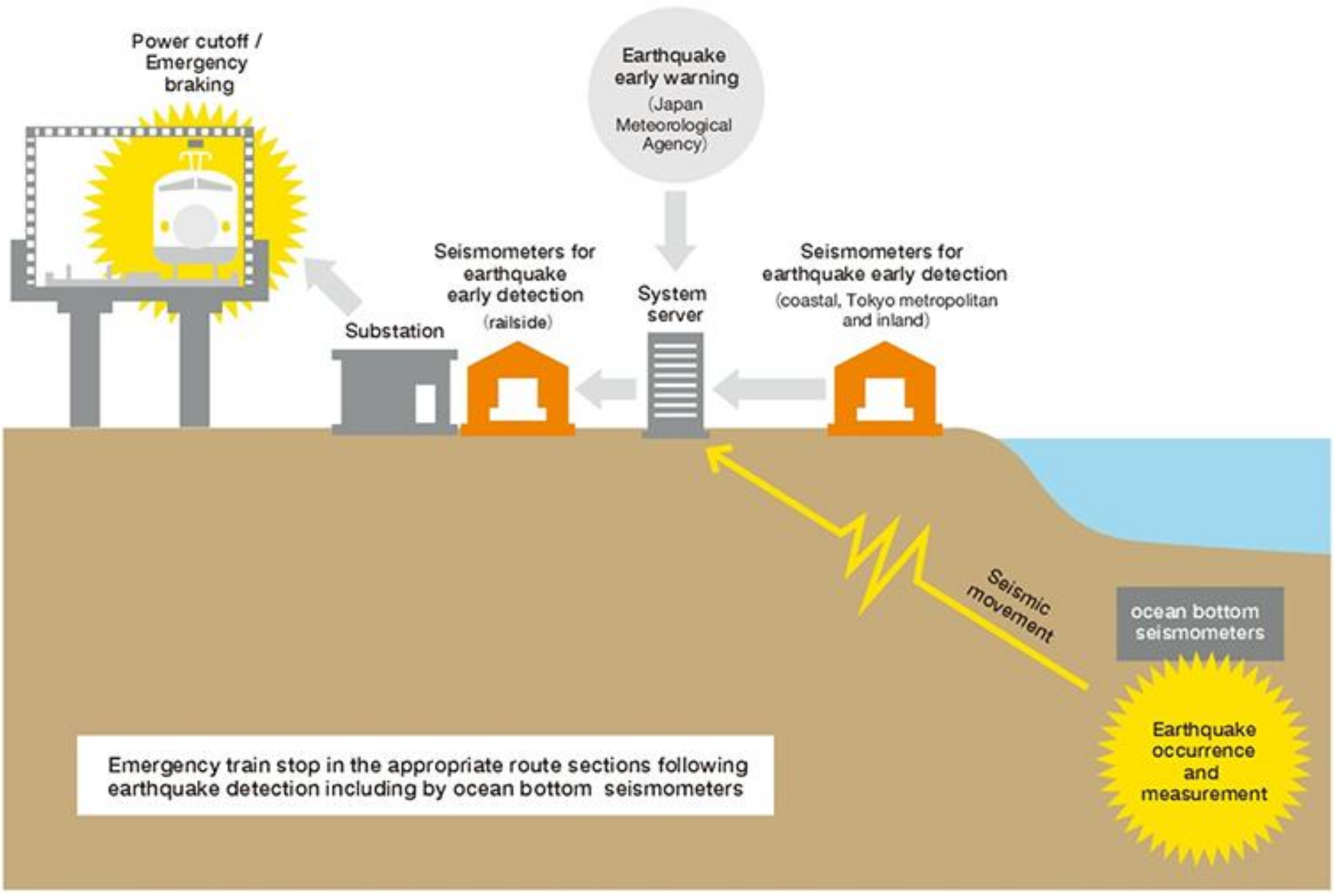

Figure 6.2 Diagram of seismometers for earthquake early detection[52]

[52]"Technologies Supporting the Future: Earthquake - Japan's Regional Charm." JapanGov. Accessed April 12, 2020. https://www.japan.go.jp/regions/resilientjapan/earthquake.html.

Table 6.1 Evidence of Resilience Constructs V (2012 – 2015)

Resilience Constructs	Summary of Evidence
Robustness	Ability to withstand “mini-shocks”
Redundancy	Not explicitly evident in technological workarounds, though there are a substantial number of coexisting lines in Tokyo by this time that could offer alternative routes.
Resourcefulness	Only two staff needed to monitor the Yamanote line at any given time. Older train models recycled to suburban lines
Rapidity	Rapid response from control team when emergency button is pressed allows for minimal system downtime

“Urbanism works when it creates a journey as desirable as the destination.”

Paul Goldberger, architecture critic

6. STATIONS

Figure 7.1 Yamanote line stations in loop[53]

Out of the fifty busiest train stations in the world, all but six of them are in Japan. Over half of them are in Tokyo, and fifteen of them exist along the Yamanote line, including the top three busiest train stations in the world.[54] To date, there are 30 stations on the Yamanote line. The six largest are Ueno, Tokyo, Shinagawa, Shibuya, Shinjuku, and Ikebukuro (Figure 7.1). An in-depth evaluation of the stations that constitute this loop line arguably gives the most notable perception of how rail transportation curates resilience in its urban context.

[53] “Planning a Trip to Japan.” MyKaiju. Accessed March 27, 2020. https://mykaiju.com/japan/.

[54]Japan Today. “The 51 Busiest Train Stations in the World– All but 6 Located in Japan.” Japan Today. Accessed March 5, 2020.

To fully grasp the functionality of these stations as they exist today, it is essential to understand how urban planning and policy in the previous century have influenced these monumental transportation hubs. The Ministry of Railways, which was fully operational until after World War II, prohibited privately-owned rails from crossing the tracks of the Yamanote.[55] Consequently, many suburban and regional lines terminate at stations along the Yamanote, explaining why Japan Railways has such a monopoly on aloft rail passenger traffic in the Greater Tokyo area. Most significantly, the termination of peripheral lines on the outer edge of the Yamanote loop indicates why major stations like Shinjuku encounter over 3.5 million passengers daily;[56] its very formation dictates the mobility of the entire city even one century later.

According to writer and activist Jane Jacobs, remembered widely for her influence on urban planning, the best way to know a city is to walk it.[57] I conducted a two-week in-person observation of the Yamanote Line in late 2019, in which I visited all six of the busiest stations in addition to several others and their surrounding context. I recorded observations relative to the stations as placemaking devices, adjacencies to emergency facilities, and ease of navigation.

[55]Terada, Katsushige. “Railways in Japan—Public & Private Sectors.” *Japan Railway & Transport Review* 27 (June 2001): 55.
[56]“Shinjuku Station Is Enormous! Daily Passengers Equivalent to Population of Yokohama.” nippon.com, March 6, 2019. https://www.nippon.com/en/features/h00273/shinjuku-station-is-enormous!-daily-passengers-equivalent-to-population-of-yokohama.html.
[57]Shea, Neil, and David Guttenfelder. “Tokyo Became a Megacity by Reinventing Itself.” National Geographic, March 14, 2019. https://www.nationalgeographic.com/magazine/2019/04/how-tokyo-japan-became-megacity-by-rebuilding-after-earthquake-war/.

Figure 7.2 Shinjuku shopping district across from Shinkuku Station[58]

Numerous stations along the Yamanote Line were devised as centers of commercial activity. The intention was to draw business to the railways by conveniently positioning stations in the most energetic areas of the city or by attracting businesses to existing stations. The case of Shinjuku Station is the most impressive example of this scheme, as it has transformed into the busiest station in the world in terms of passenger throughput.[59] Not only is Shinjuku station a major transfer terminal, but it also marks the center of one of the most thriving shopping districts in Japan (Figure 7.2). According to transport industry experts, the convenience of stations like Shinjuku to highly populous areas represents redundancy by offering a collection of alternative routes to and from commercial activities.

Figure 7.3 A crowd of pedestrians cross the iconic Shibuya Crossing on December 30, 2019[61]

Similarly, Shibuya Station claims territory in another famous district in Tokyo. This district is most well-known for Shibuya Crossing, or Shibuya Scramble (Figure 7.3), the world's single busiest crosswalk

[58] Mount, Harry. "Japan, a Fascinating Country Undimmed by Disaster and Very Much Back on Its Feet." Daily Mail Online. Associated Newspapers, March 2, 2012. https://www.dailymail.co.uk/travel/article-2109380/Japan-fascinating-country-undimmed-disaster-feet.html.

[59] Sarah. "The World's Busiest Train Stations." Railway Technology, January 28, 2020. https://www.railway-technology.com/features/featureworlds-busiest-train-stations/.

where an estimated 2,500 pedestrians[60] cross every minute. Many tourists visit Shibuya purely for this landmark, which happens to flow directly out from an exit from Shibuya Station (Appendix A: Stations). One would not typically imagine a crosswalk outside a train station as a must-see tourist destination, but

this kind of place-making facilitates the utilization of Shibuya Station and, therefore, commuter lines like the Yamanote.

Figure 7.4 Tokyo Station[61]

Tokyo Station (Figure 7.4) is one of the most iconic stations along the Yamanote loop. Alternatively known as Marunouchi station, it was designed by famous Japanese architect Kingo Tatsuno

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[60] Misachi, John. "The World's Busiest Pedestrian Crossing." WorldAtlas. WorldAtlas, March 5, 2018. https://www.worldatlas.com/articles/what-is-the-world-s-busiest-pedestrian-crossing.html.

[61] Author

and originally opened in 1914.[62] Its Renaissance architecture[62] is a focal point for many visitors, and its broad plaza extends from the station entrance to the Imperial Palace.[62] The expansive plaza serves as a pleasant public space, and people who desire to experience it are drawn to the commuter railways.

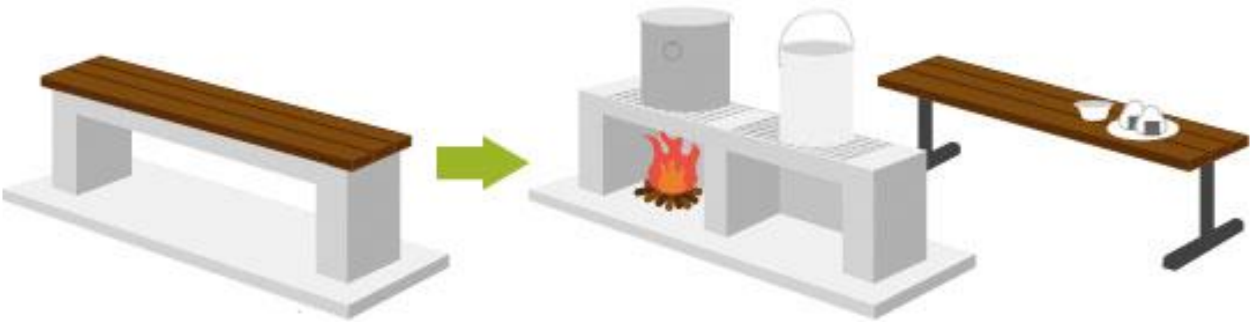

Figure 7.5 Instructional diagram demonstrating emergency bench[63]

The value of transport convenience through place-making and public space expands when considering the adjacency of stations to emergency facilities, including public parks. All major parks in Tokyo are disguised as survival bunkers should large masses become stranded following a disaster.[64] The parks are fitted with benches that convert into stoves (Figure 7.5) and solar-powered charging stations for cell phones and electric bicycles. In fenced-off areas, a grid of manholes doubles as public restrooms.[8] The covers are removed, and special seats and tents are placed over them.[65] Water reservoirs and storehouses camouflaged in the ground contain enough food to last an entire ward for the first 72 hours following a disaster,[8] which the Tokyo Rinkai Disaster Prevention Park (Appendix B:

[62]"The Restored Symbol of the Metropolitan City - Tokyo Station: JAPAN Monthly Web Magazine." The restored symbol of the Metropolitan City - Tokyo Station | JAPAN Monthly Web Magazine. Accessed April 8, 2020. https://japan-magazine.jnto.go.jp/en/1212_tokyost.html.

[63]"Facilities for Disaster Prevention in the Park." Facilities for Disaster Prevention in the park | Let's study Disaster Prevention Parks Disaster Prevention Parks keep the safety in the city | Let's go to the park! Accessed April 10, 2020. https://www.tokyo-park.or.jp/special/bousai/english/sisetsu.html.

[64]Mckean, Cameron Allan. "Tokyo's Disaster Parks: Hi-Tech Survival Bunkers Hidden under Green Spaces." The Guardian. Guardian News and Media, August 19, 2014. https://www.theguardian.com/cities/2014/aug/19/tokyo-disaster-parks-hi-tech-survival-bunkers-hidden-green-spaces-earthquake.

[65]Hurst, Daniel. "'This Is Not a 'What If' Story': Tokyo Braces for the Earthquake of a Century." The Guardian. Guardian News and Media, June 12, 2019. https://www.theguardian.com/cities/2019/jun/12/this-is-not-a-what-if-story-tokyo-braces-for-the-earthquake-of-a-century.

Facilities) says is the most critical time frame for survival. In addition to coordinating emergency response efforts, the Rinkai facility offers free earthquake simulations and a 72-hour simulation tour (Figure 7.6) to educate the public and to evaluate them on their survival skills (Figure 7.7) during those first three critical days. Some of the skills taught include the operation of emergency mechanisms in public parks. In Tokyo, it is often required by landlords and employers to take the tour intermittently, thereby ensuring the safety of the public.

Figure 7.6 (left) Tokyo Rinkai Prevention Park post-disaster simulation,[9] Figure 7.7 (right) post-disaster simulation evaluation[9]

If the trains lose function and passengers become stranded, passengers can retreat to nearby public parks. Amongst the emergency survival-equipped parks within walking distance of Yamanote stations are Shinjuku Gyoen National Garden, Kokyo Gaien National Garden, Yoyogi Park, Ueno Park, and Shinjuku Chuo Park (Figure 7.8). Where the inconvenience of inability to return home meets convenient alternatives is the demonstration of redundancy in resilient transport networks. Additionally, where the loss in functionality of the trains may occur, the multipurpose parks create a secondary means of resourcefulness.

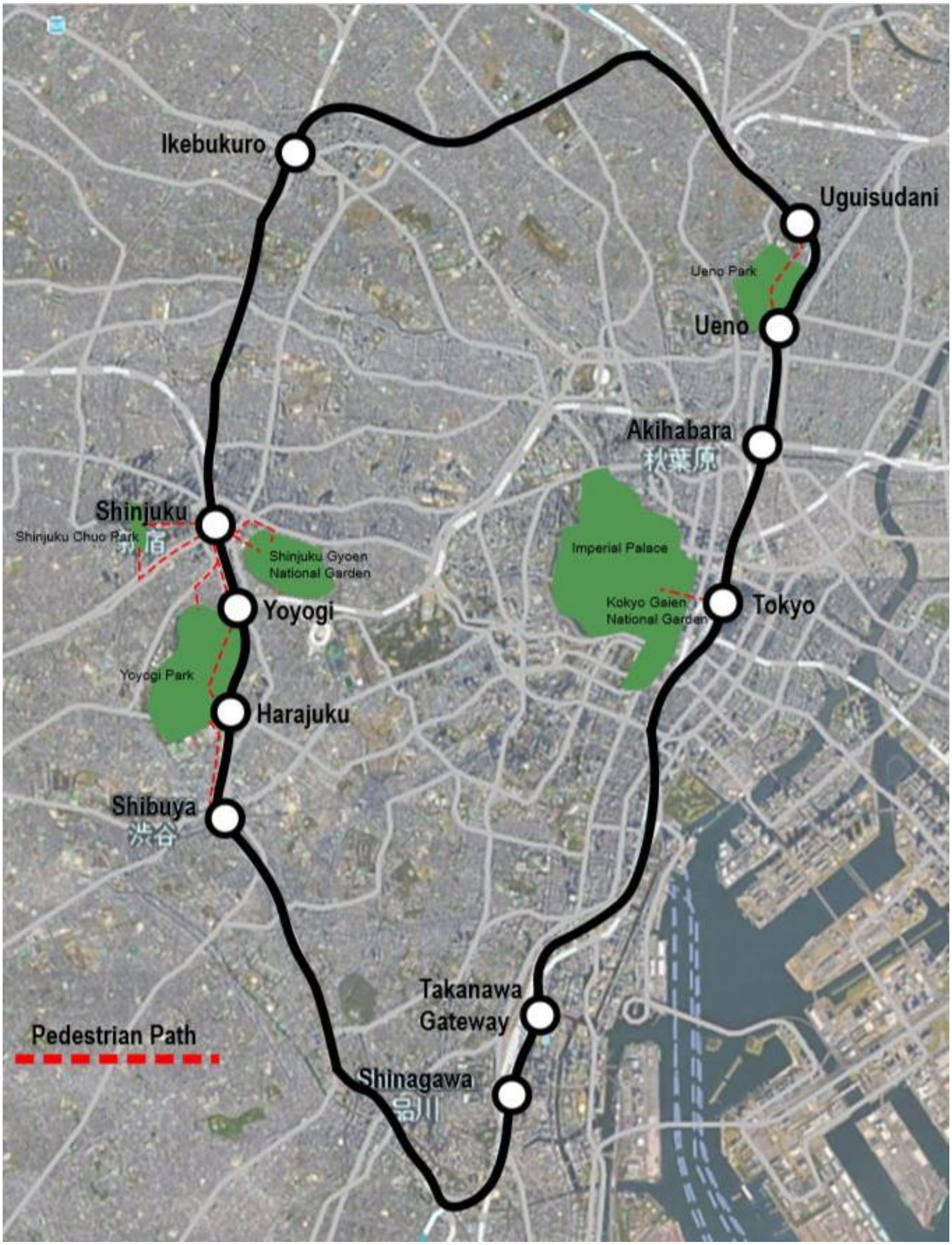

Figure 7.8 selected examples of alternative pedestrian routes through emergency mechanism-equipped parks from Yamanote Line stations[9]

In the case of overcrowded stations and long wait times, the nearby parks stretch from one station to another offer a pleasant walk as an alternative means of transport (Appendix C: Maps and Timelines). The most applicable example is Yogogi Park, which borders both Yoyogi Station and Harajuku Station. Harajuku is arguably the most overcrowded neighborhood in Tokyo. Located in the Shibuya ward, this iconic center of underground fashion culture draws such massive crowds that the undersized Harajuku train station simply cannot keep up (Figure 7.9). Traffic guards frequently direct passengers trying to enter the station to walk to the nearest JR station or underground terminal. Yoyogi Park, formerly the site of the 1964 Olympic village, borders Harajuku station and stretches north towards the less-crowded Yoyogi station. A pleasant 15-minute walk through the park takes less time than waiting to enter the Harajuku station on its busiest days. It also saves money on passenger fares, provides exercise, and is one of the safest placesin the city to be during an emergency. Another example of this alternative route between stations is Ueno Park that bridges Ueno and Uguisudani stations.

Figure 7.9 crowded Takeshita street across from Harajuku station[9]

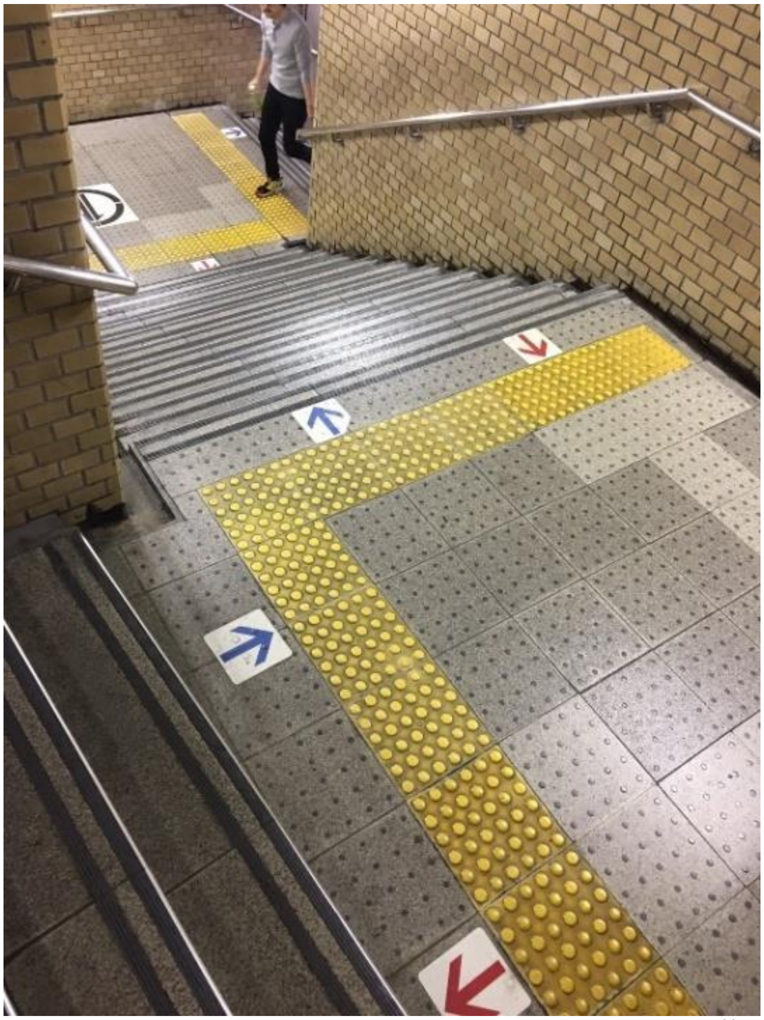
Figure 7.11 arrows mark paths for passengers in station corridors[66]

Some of the largest stations may be confusing or overwhelming for non-locals to navigate. Fortunately, all stations are cleverly designed and organized to keep navigation as simple as possible and to efficiently facilitate millions of passengers every day. Every station in Tokyo is marked with arrows on the ground (Figure 7.11), communicating to passengers which side of the corridor to walk. This is a simple but effective way to keep crowds of people organized and prevent chaos. On platforms, marks on the ground designate space for passengers to stand while waiting for the next train. Doing so eliminates shoving and allows other passengers to comfortably exit the train. The organizational practices in the station carries over to the trains as well. In Japan it is culturally appropriate to stand in organized lines

[66]Galante, Guillaume. “What Tokyo's Metro Taught Me about Progressive Disclosure.” Medium. UX Collective, November 14, 2018. https://uxdesign.cc/what-tokyos-metro-taught-me-about-progressive-disclosure-eae4502af617.

once in the train car. This is done out of courtesy to other passengers, but it also means reduced chaos should the train lose function. The Tokyo Metropolitan Government created a detailed manual on how to respond in an earthquake. Figure 7.12 shows an extract from the manual on what to do if an earthquake happens when riding a train or standing on a railway platform.

Figure 7.12 excerpt from disaster preparedness manual 'Let's Get Prepared'[67]

The newest station is Takanawa Gateway (Figure 7.13), a 500-billion-yen project designed by Kengo Kuma that officially opened on March 14, 2020. Prior to 2020, the most recent station to open is Nishi-Nippori, which was unveiled in April of 1971.[68] Four hundred years ago, the Takanawa area was the gateway to Tokyo, then called Edo.[69] It is located near the Shinagawa Station, which handles an

[67] "Disaster Preparedness Tokyo." Tokyo Metropolitan Government. Accessed March 27, 2020. https://www.metro.tokyo.lg.jp/english/guide/bosai/index.html.

[68] "Tokyo's Yamanote Line: More Than You Ever Wanted To Know." DeepJapan. Accessed March 27, 2020. http://www.deepjapan.org/a/4472.

[69] "Japan Rail Journal," n.d.

increasing number of passengers traveling to and from international airports. Therefore, the new Takanawa Station serves as a gateway for this Japanese business center to the rest of the world. The timber used to construct the station's wooden pillars comes from the Tohoku region in support of the Tohoku economy following the recent earthquake.[69] Additionally, energy harvested from photovoltaic panels on the roof powers the station, eliminating the reliance on non-renewable energy sources.[69] Table 7.1 shows the summarized evidence of resilience displayed by the Yamanote Line from the years 2016 to 2020.

Figure 7.13 Yamanote Line train stopped at Takanawa Gateway on opening day[70]

[70] "Takanawa Gateway Opens." Railway Gazette International, March 17, 2020. https://www.railwaygazette.com/infrastructure/takanawa-gateway-opens/56033.article.

Table 7.1 Evidence of Resilience Constructs VI (2016 – 2020)

Resilience Constructs	**Summary of Evidence**
Robustness	Many stations along Yamanote have survived more than a century. Stations can accommodate millions of passengers every day
Redundancy	the convenience of stations like Shinjuku to highly populous areas represents redundancy by offering a collection of alternative routes to and from commercial activities. Place-making of railway stations facilitates utilization of commuter railways, which then warrants further development and refinement Adjacency of stations to emergency facilities like public parks equipped with post-disaster survival mechanisms Alternative and pleasant routes through nearby parks Organized and easily navigable stations
Resourcefulness	Energy harvested from stations, demonstrated in photovoltaic panels on the roof of Takanawa Gateway; the opportunity for energy recycling could prove useful in the future of railway development. Perhaps one day the harvesting of kinetic energy from frequent seismic activity could be converted to electricity and used to power stations and trains.
Rapidity	One loop around the Yamanote takes approximately one hour, whereas to walk that same distance (34.5 kilometers) can take anywhere from 5.5 to 9 hours. This is an incredibly efficient and convenient way to cover a broad expanse of urban area in a short amount of time.

“Resilience isn’t just Tokyo; it’s a Japanese characteristic.”

Koike, Tokyo’s first female governor

8. CONCLUSION

8.1 Lessons Learned

Figure 8.1.1 a Yamanote Line train approaches Ueno Station[71]

Tokyo, Japan (Figure 8.1.1) has come a long way since its modest beginnings as a small fishing village. A city that has entirely built itself twice in the twentieth century, endured decades of economic stagnation, and trembled in some of the most historic natural disasters has demonstrated to the world its ability to flourish when faced with some of the most complex problems. Its upbringing reveals that cities do not transform themselves overnight. Even the most vibrant urban centers must anticipate and adapt to change, and Tokyo has done so in countless innovative ways.

The railway transportation network in Japan is nothing short of revolutionary. What began as meager cargo lines transformed into a simple yet sophisticated commuter railway. When ravaged by an

[71]"The JR Yamanote Line: Getting around Tokyo." Japan Rail Pass, March 18, 2020. https://www.jrailpass.com/blog/yamanote-line.

earthquake and fire, officials discovered an opportunity to rebuild a stronger city and sensibly complete the loop of the Yamanote as part of their plan.

When the economy was slow, the government still found transportation a worthy industry for development. This strategic investment generated new business and permitted Tokyo to expand into the most populated city on Earth.

In the decades since the last two major disasters to strike the city, Tokyo has not waited for another catastrophe to provide an opportunity for change. Planners devised ways to adapt its existing urban fabric into a more resilient framework. Recycling outdated train models to suburban lines, creating pleasant alternative means of transport, arming public parks with survival mechanisms that can provide well-being should the trains fail, and utilizing train stations as place-making devices are merely a few strategies for resilient development that Tokyo has implemented. It is important to note that these strategies do not always require a first-world economy to achieve. In fact, several of the schemes outlined are successful because of cooperation amongst city officials and not solely because of financial resources.

While it is clear the Yamanote Line is a resilient means of transportation, its contribution to Tokyo’s overall resilience is not self-dependent. Cities are incredibly complex entities that rely on the interconnection of various components to operate. Without the continuous function of other infrastructure, rail transportation, including the Yamanote Line, would undoubtedly fail. It is no less true that the Yamanote Line enhances the performance of Tokyo. This neon-green colored train is unlikely the first picture that comes to mind when thinking about Tokyo, but without it, it is difficult to imagine a Tokyo that looks anything like it does today. The development of this railway line over the last 150 years suggests that strong railway networks can potentially make cities more resilient to natural disasters and better equipped for their inevitable evolvement.

8.2 Looking to the Future

Shimoyama, JR East Facilities Department general manager says, “When it comes to earthquake safety measures, we can never say that we have done enough.”[72] The ever-changing nature of cities indicates that there is always room for improvement, and rail transportation is no exception. Experts estimate that a magnitude-7 earthquake has a 70% chance of hitting Tokyo before 2050.[73] This kind of event would be the greatest shock to the city since the airstrikes of World War II. Such a frightening reality means that vulnerable cities like Tokyo will have to work hard to ensure the safety of their inhabitants. Along with seismically reinforced buildings, frequent emergency drills, the world’s largest fire brigade, and educational resources like the 338-page manual “Let's Get Prepared,“[73] the Japanese are working to develop an even more advanced transportation system.

In January 2019, East Japan Railway began testing a driverless system for local trains.[74] The intention for self-driving trains is to make up for a predicted shortage of train operators with the aging population.[74] The advanced system can also vary its speed for optimal efficiency according to the environment and distance between stations.[74] There are still plenty of errors needing resolution before the system can officially be employed. Still, it is certainly possible that self-driving trains may become the future of railway transportation in Tokyo.

Tokyo was the host of the 1964 Olympic Games, and in 2021 the city will welcome visitors from all over the world to this historic event for a second time. The event could put an unprecedented strain on railways and highways. The newest station along the Yamanote, the Takanawa Gateway, opened on schedule in the spring of 2020 to accommodate the influx of people.

[72]“Technologies Supporting the Future: Earthquake - Japan's Regional Charm.” JapanGov. Accessed April 12, 2020. https://www.japan.go.jp/regions/resilientjapan/earthquake.html.

[73]Hurst, Daniel. “'This Is Not a ‘What If’ Story': Tokyo Braces for the Earthquake of a Century.” The Guardian. Guardian News and Media, June 12, 2019. https://www.theguardian.com/cities/2019/jun/12/this-is-not-a-what-if-story-tokyo-braces-for-the-earthquake-of-a-century.

[74]“Japan Rail Journal,” n.d.

Beginning in December of 2019, the COVID-19 pandemic spread uncertainty to the world and affected at least 176 countries, including Japan.[75] The pandemic delayed the Tokyo Olympic Games and will likely radically alter daily life long after the situation is generally considered resolved. The resumption of regular business and school operations is unlikely to occur without modifications to the functioning of public transportation. An unprecedented crisis of this magnitude in modern times forces cities to reconsider how the public interacts. Designers and planners will undoubtedly face a new concern for resilience in cities—one that has as much to do with planning for monumental singular-moment disasters as it does with preventing equal or greater magnitude crises originating from a deceptively mundane, microscopic level scale.

Figure 8.2.1 A man wearing a protective face mask walks past the Olympic Rings following the outbreak of COVID-19 in Tokyo, Japan on March 13, 2020.

[75] "World Map." Centers for Disease Control and Prevention. Centers for Disease Control and Prevention, April 8, 2020. https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/world-map.html.

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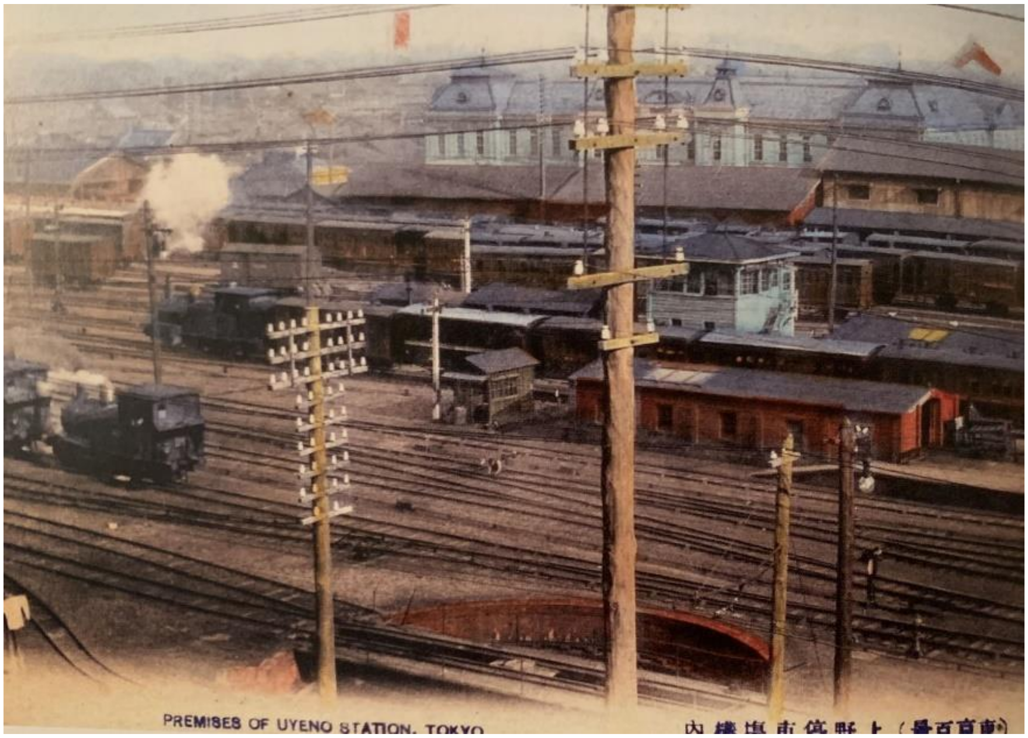
APPENDICES

Appendix A: Stations



1. Ueno Station, early 20th century[1]

2. Ueno Station, early 20th century[1]

[1]*The Reconstruction of Tokyo*. Tokyo: Tokyo Municipal Office, 1933.

3. Ueno Station, 2019[2]

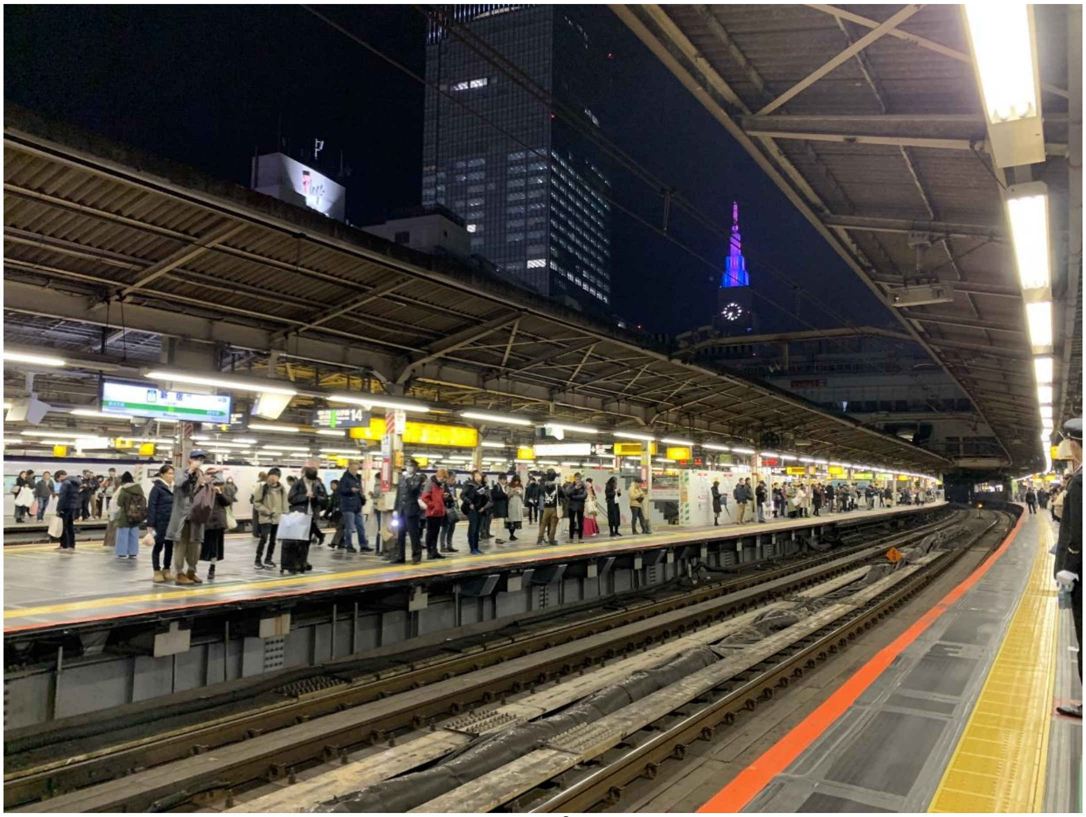
4. Plaza outside Shinagawa Station east exit, 2019[2]

[2]Author

5. Shinagawa Station east exterior, 2019[2]

6. Shinagawa Station corridor, 2019[2]

7. Shinagawa Station corridor, 2019[2]



8. Yamanote Line platform, 2019[2]

9. Yamanote Line and Keihin-Tohoku Line platforms, 2019[2]

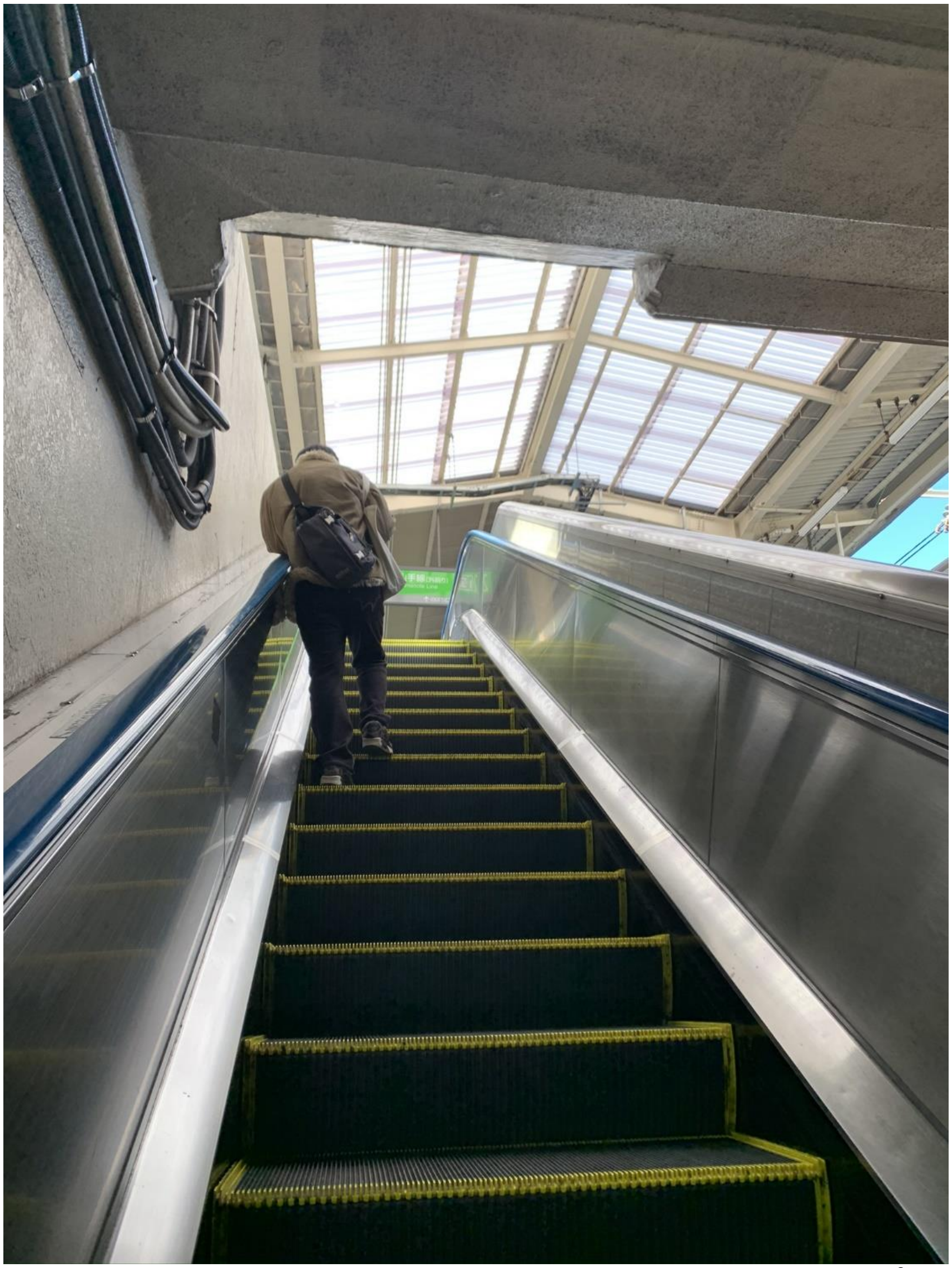
10. Yamanote Line platform, 2019[2]

11. Crowd gathered in Tokyo Station plaza, 2019[2]

12. Train station platform, 2019[2]

13. Shibuya Crossing outside Shibuya Station, 2019[2]

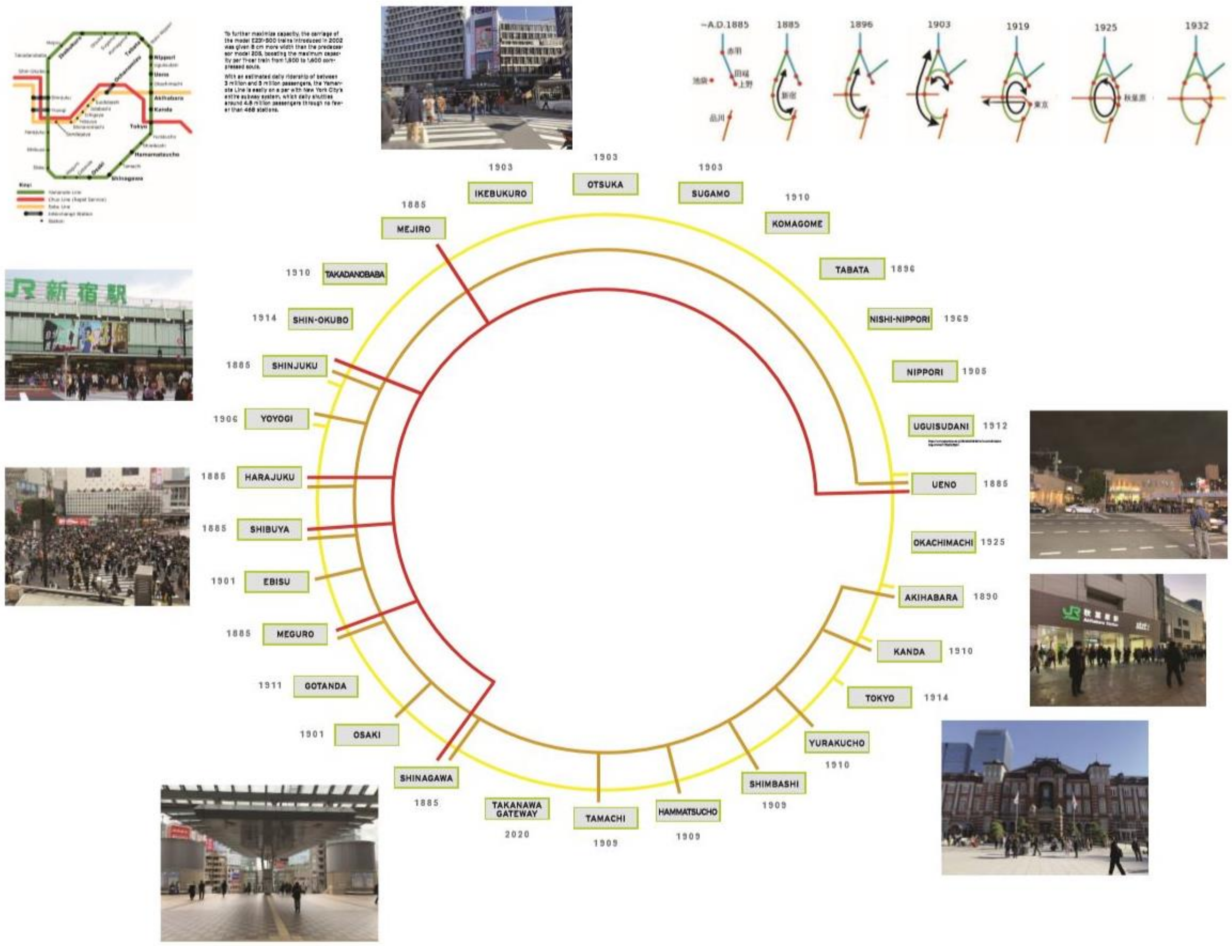
14. Shibuya Crossing outside Shibuya Station, 2019[2]



15. Man stands to the left side of escalator out of courtesy to other passengers[2]

16. Akihabara Station, 2019[2]

17. Ikebukuro Station, 2019[2]



18. Stations diagram thumbnail[2]

Appendix B: Facilities

1. Ikebukuro Life Safety Training Center

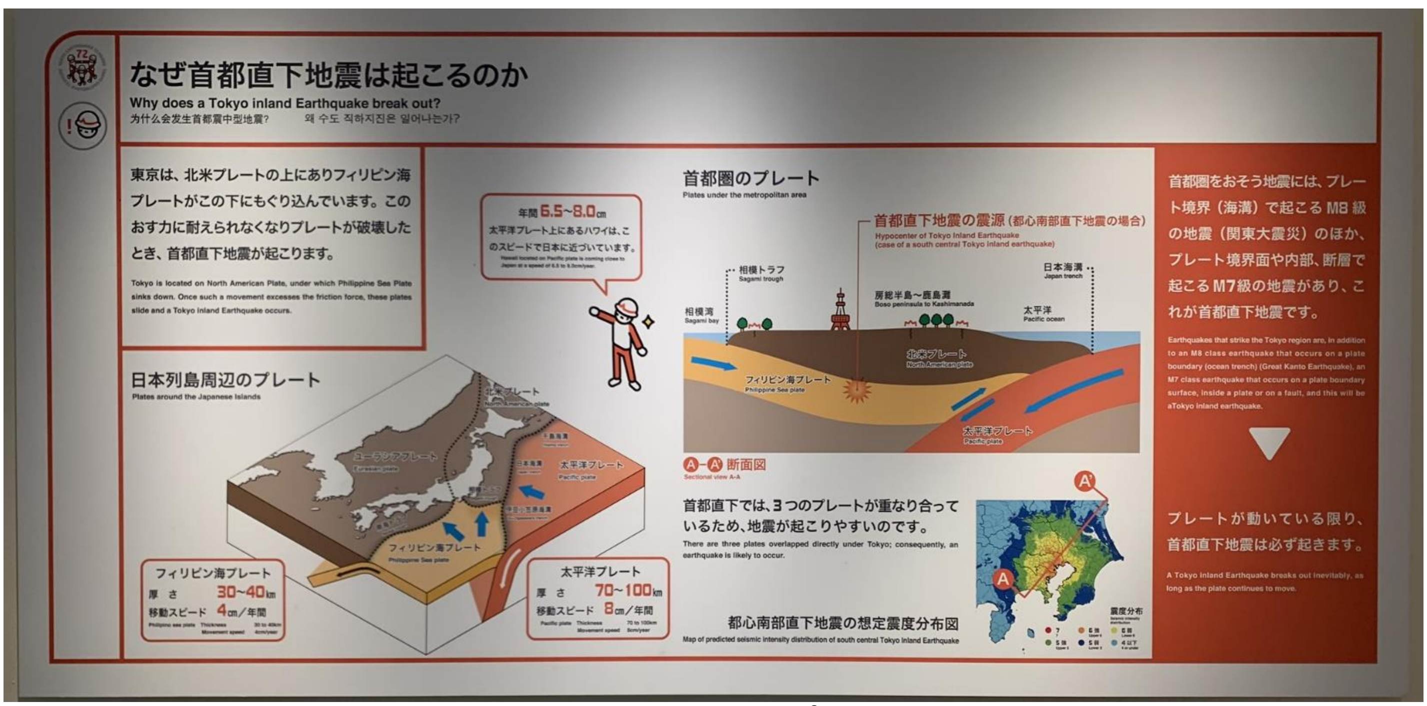
2. Tokyo Rinkai Disaster Prevention Park exterior[2]

3. Tokyo Rinkai Disaster Prevention Park main entrance[2]

4. Demonstration of survival mechinaism at Tokyo Rinkai Disaster Prevention Park[2]

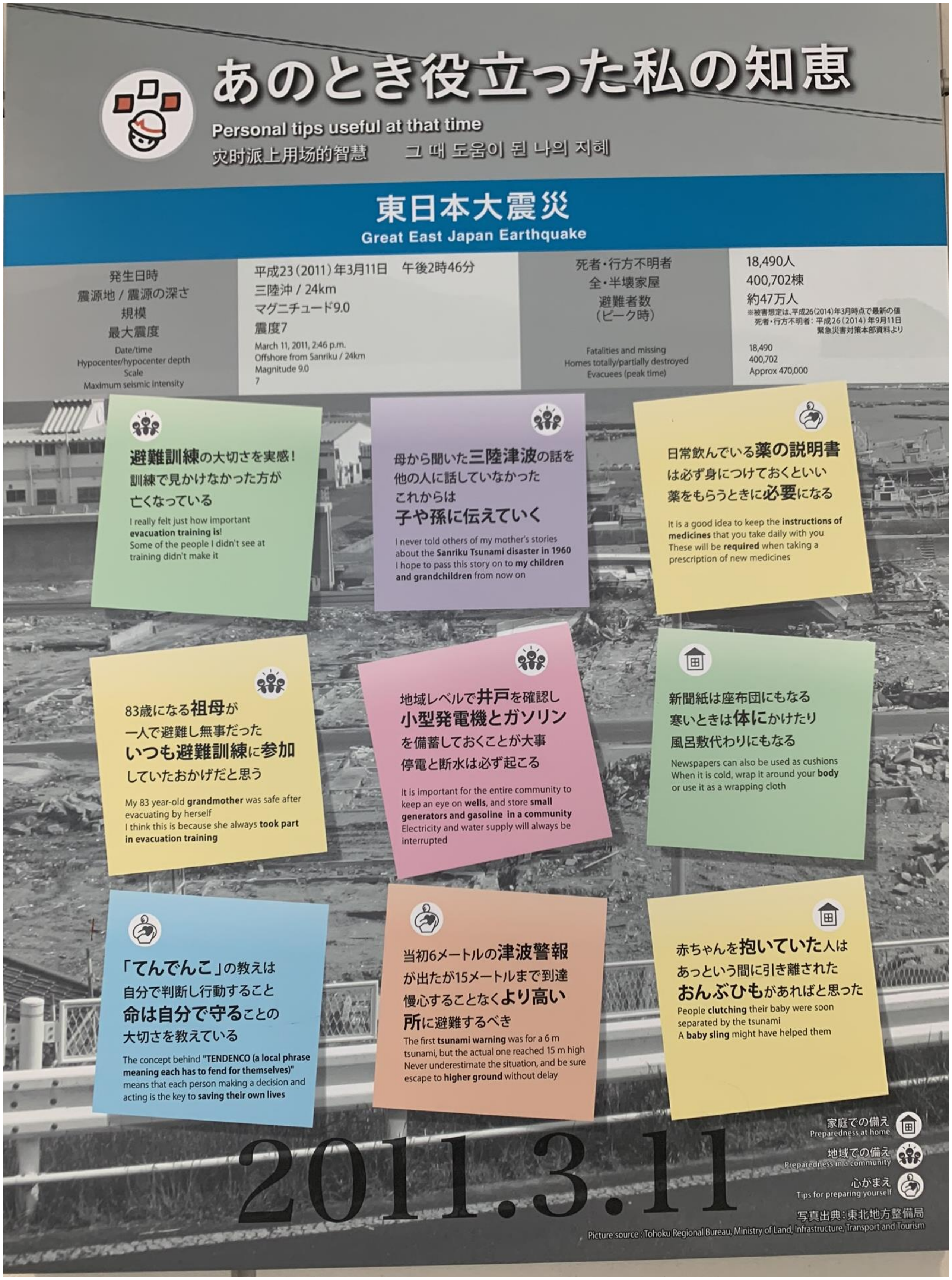

5. Vacant operation controls room at Tokyo Rinkai Disaster Prevention Park[2]

6. Diagram 'About the earthquake' and 'Source of the force that applies to the plate and base rock[2]

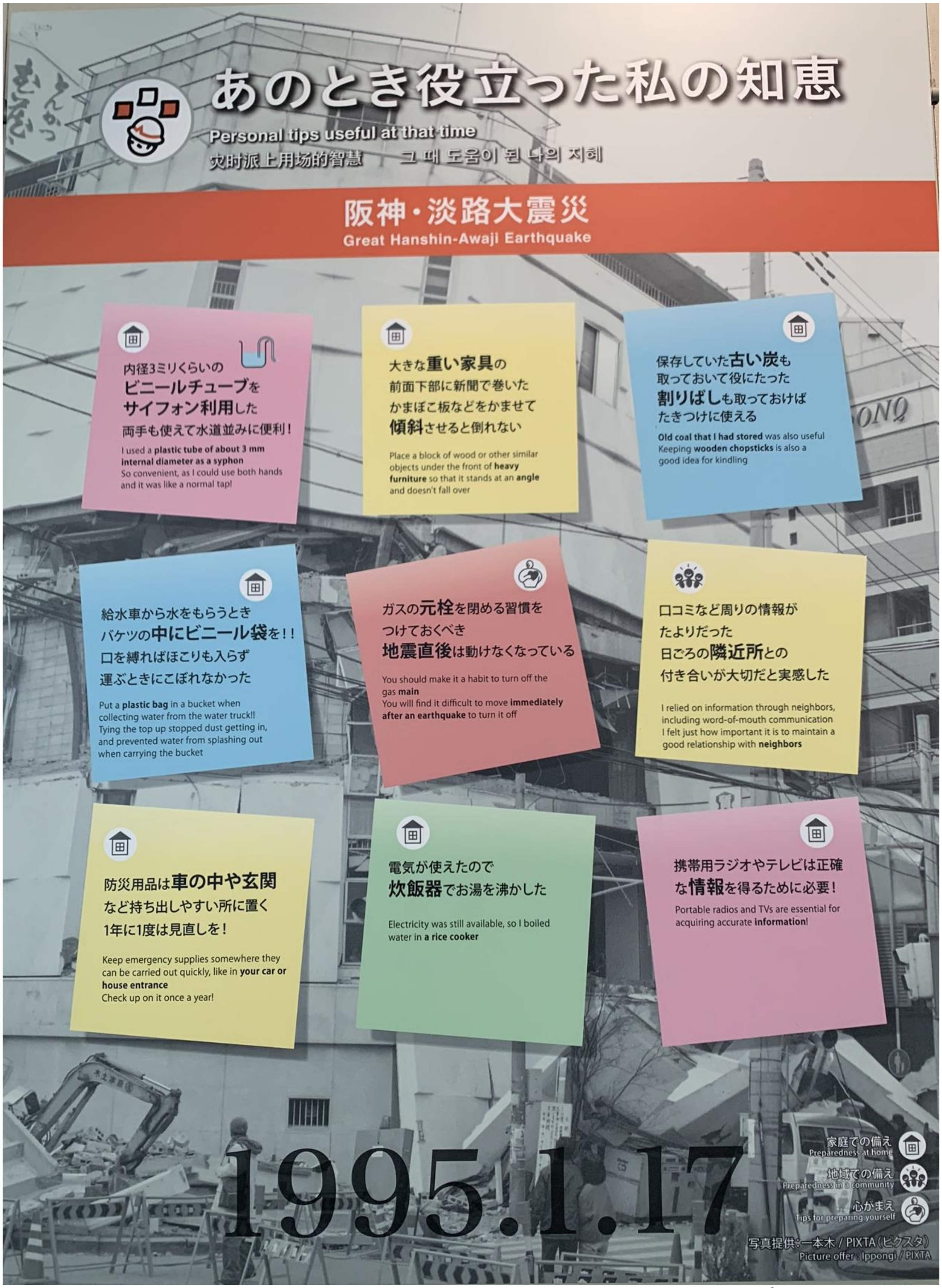


7. Diagram 'Why does a Tokyo inland earthquake break out?'[2]

8. Diagram of ‘Actions by the national government in the event of disaster’ at Tokyo Rinkai Disaster Prevention Park[2]

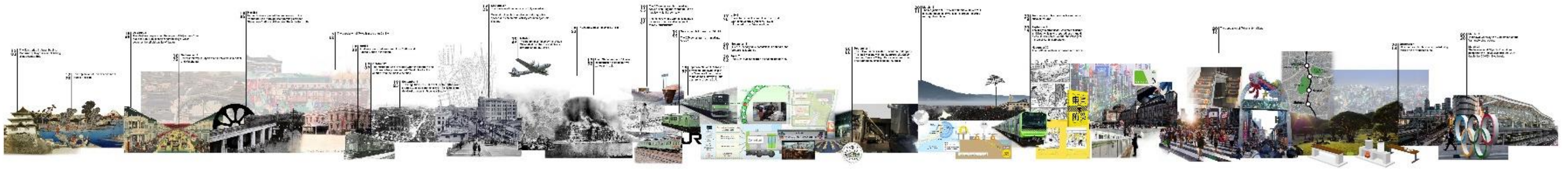


9. ‘Personal Tips useful of that Time’ accounts from Great East Japan earthquake[2]

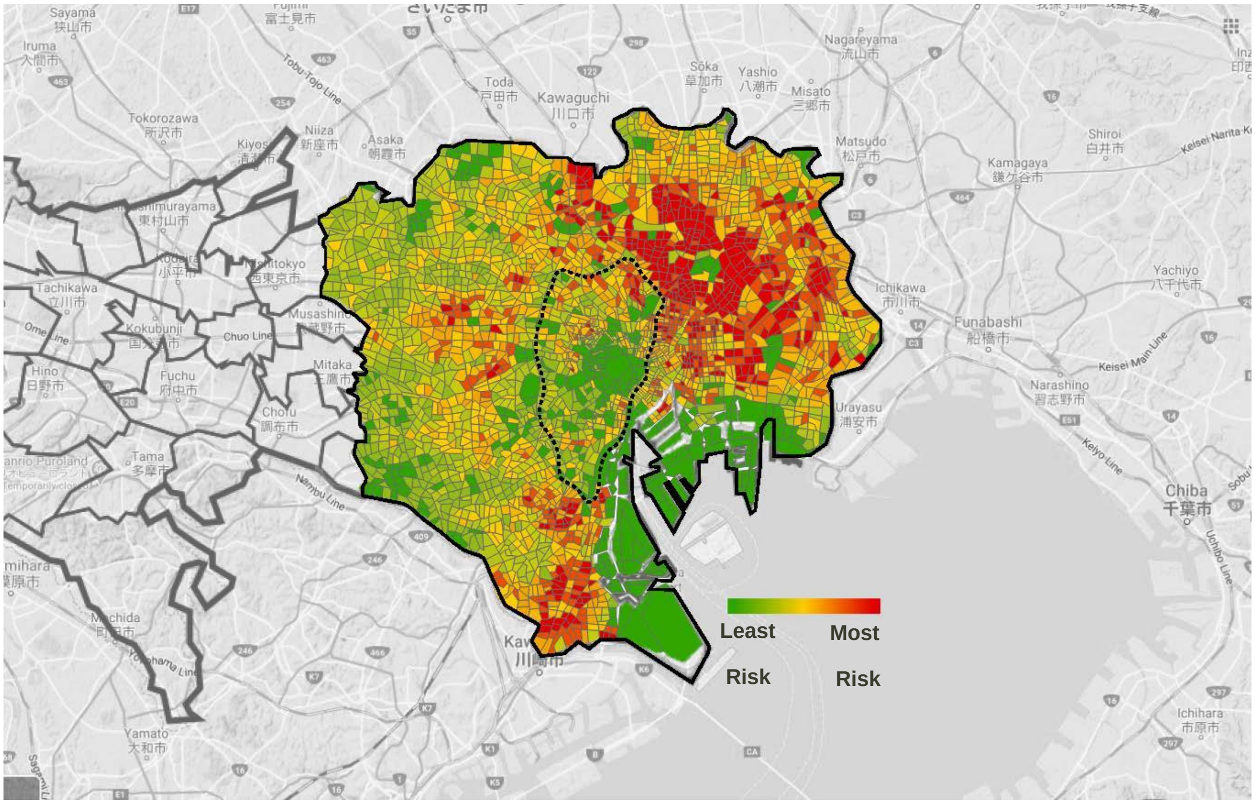


10. 'Personal Tips useful of that Time' accounts from Great Hanshin-Awaji Earthquake[2]

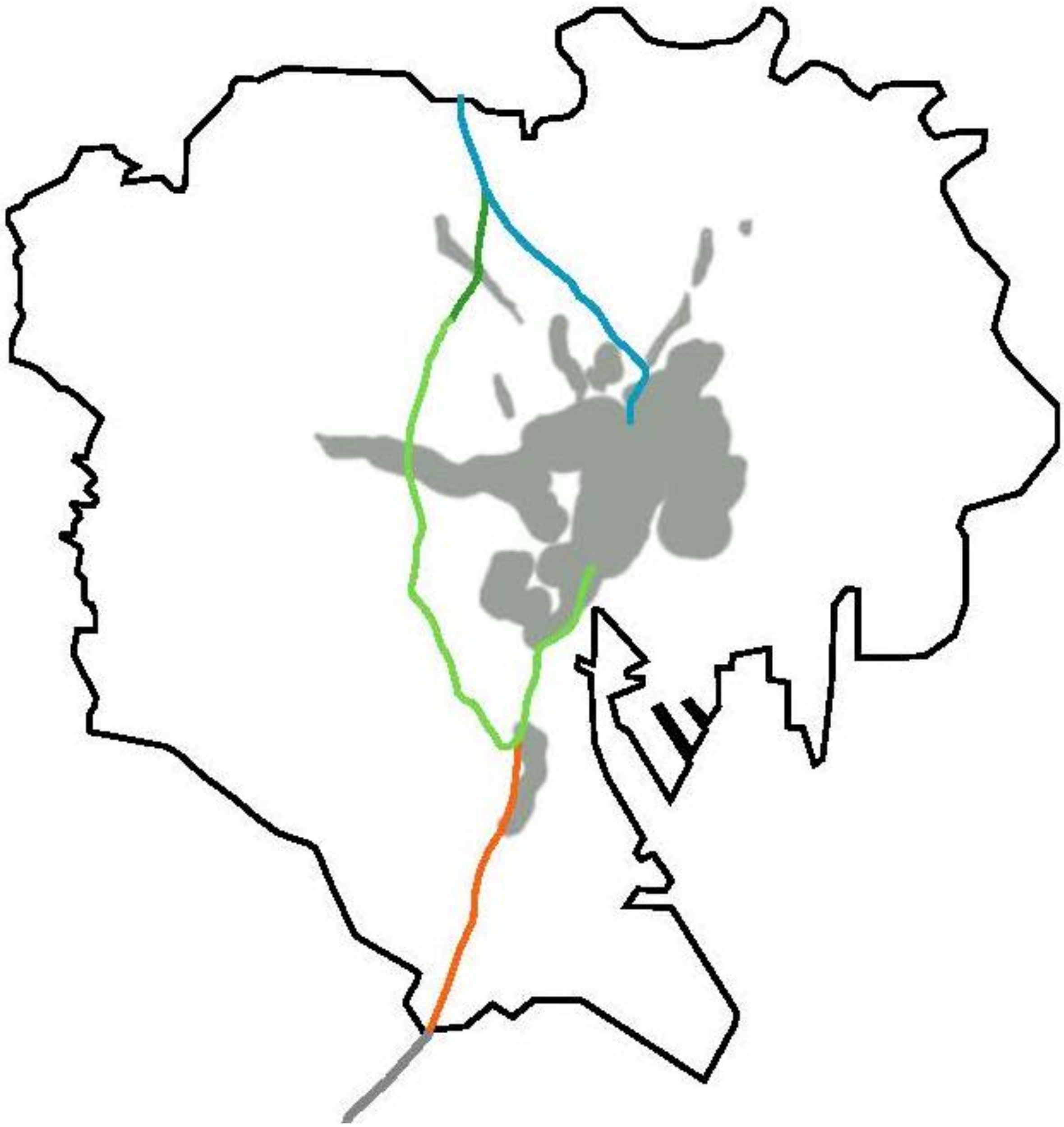
Appendix C: Maps and Timelines



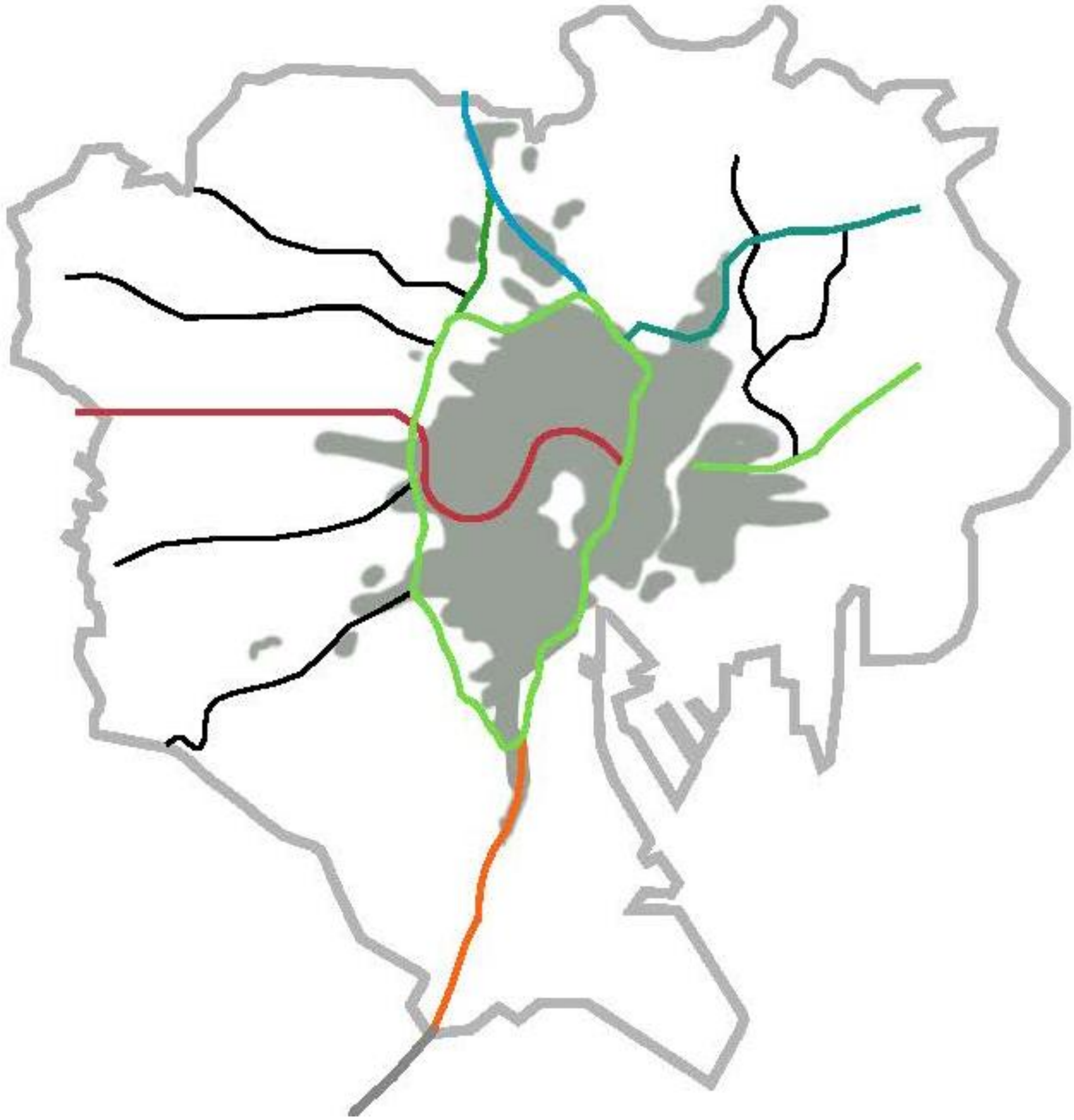
1. Timeline thumbnail[2]



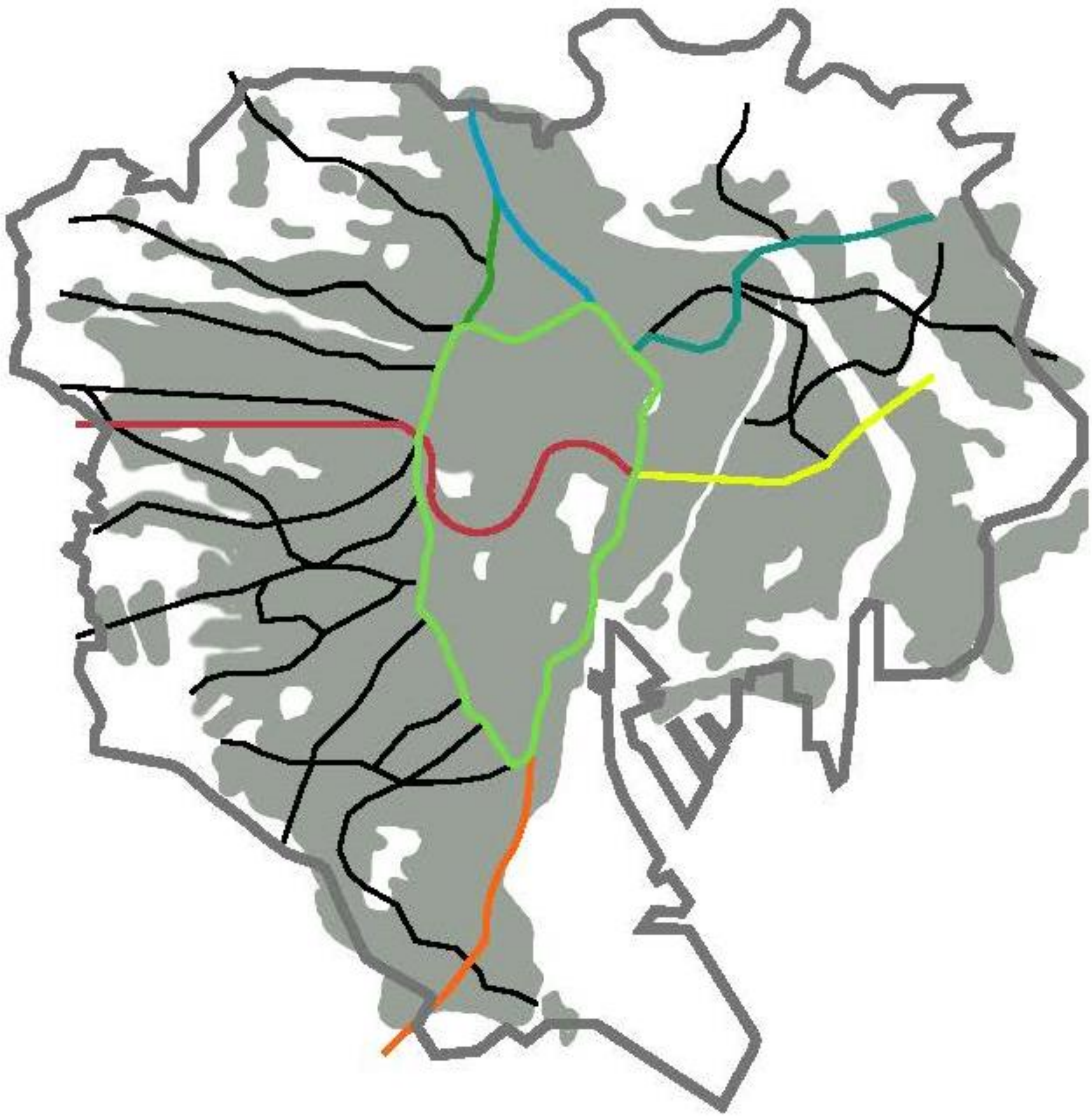
2. Yamanote Line and Tokyo disaster risk map[2]



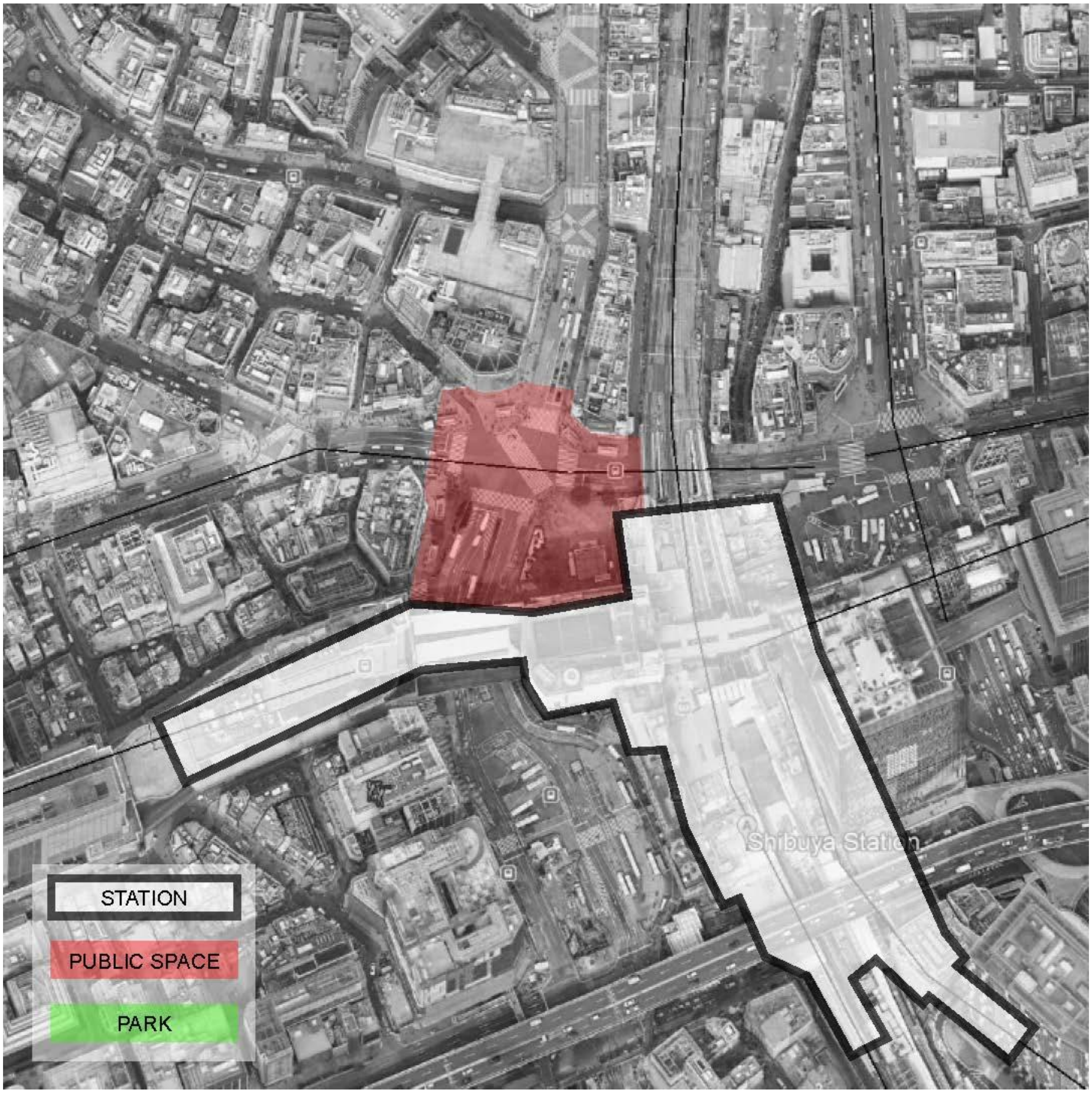
3. Yamanote Line Map and Tokyo Density 1885[2]



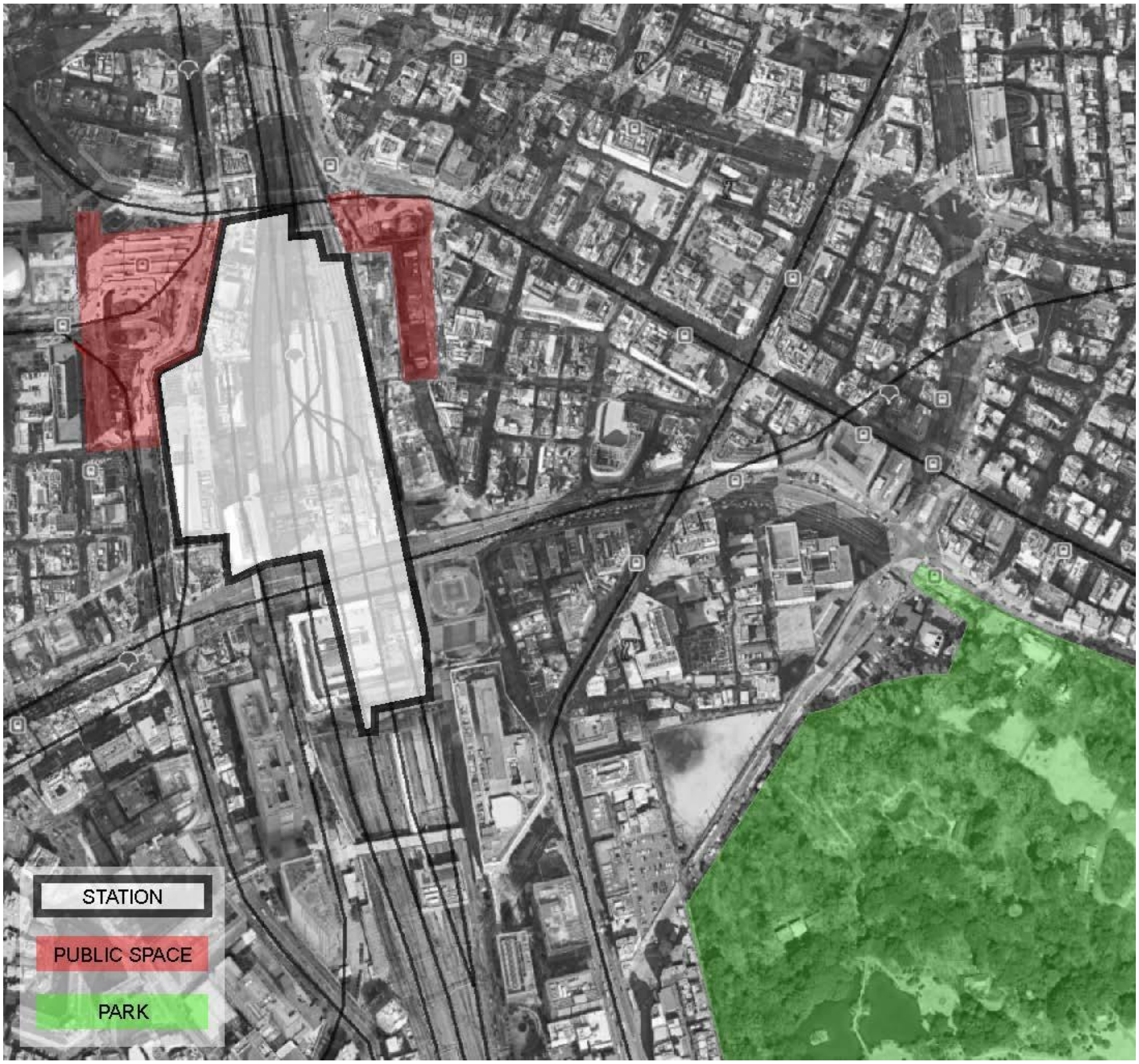
4. Yamanote Line Map and Tokyo Density 1926[2]



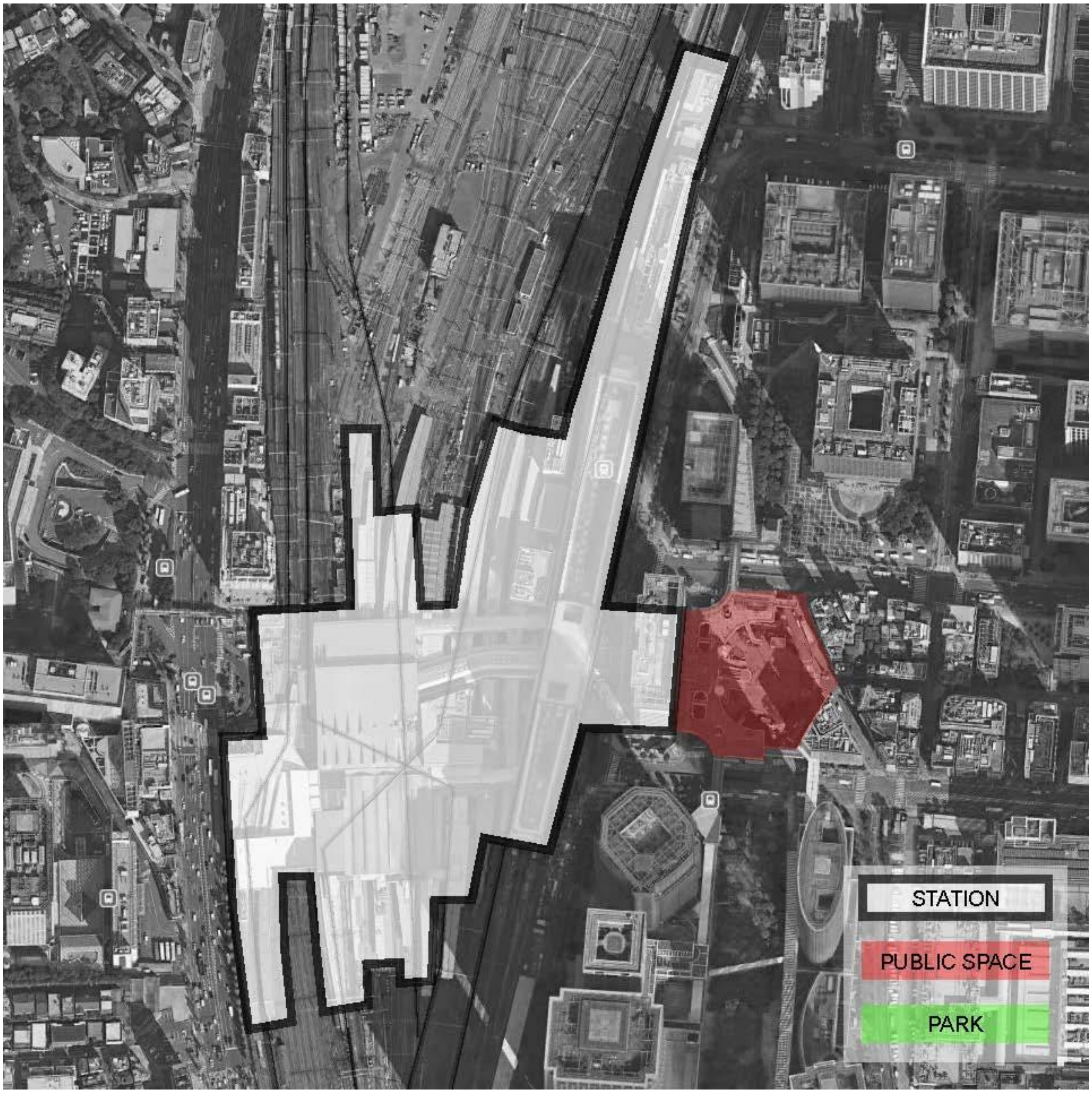
5. Yamanote Line Map and Tokyo Density 1955[2]



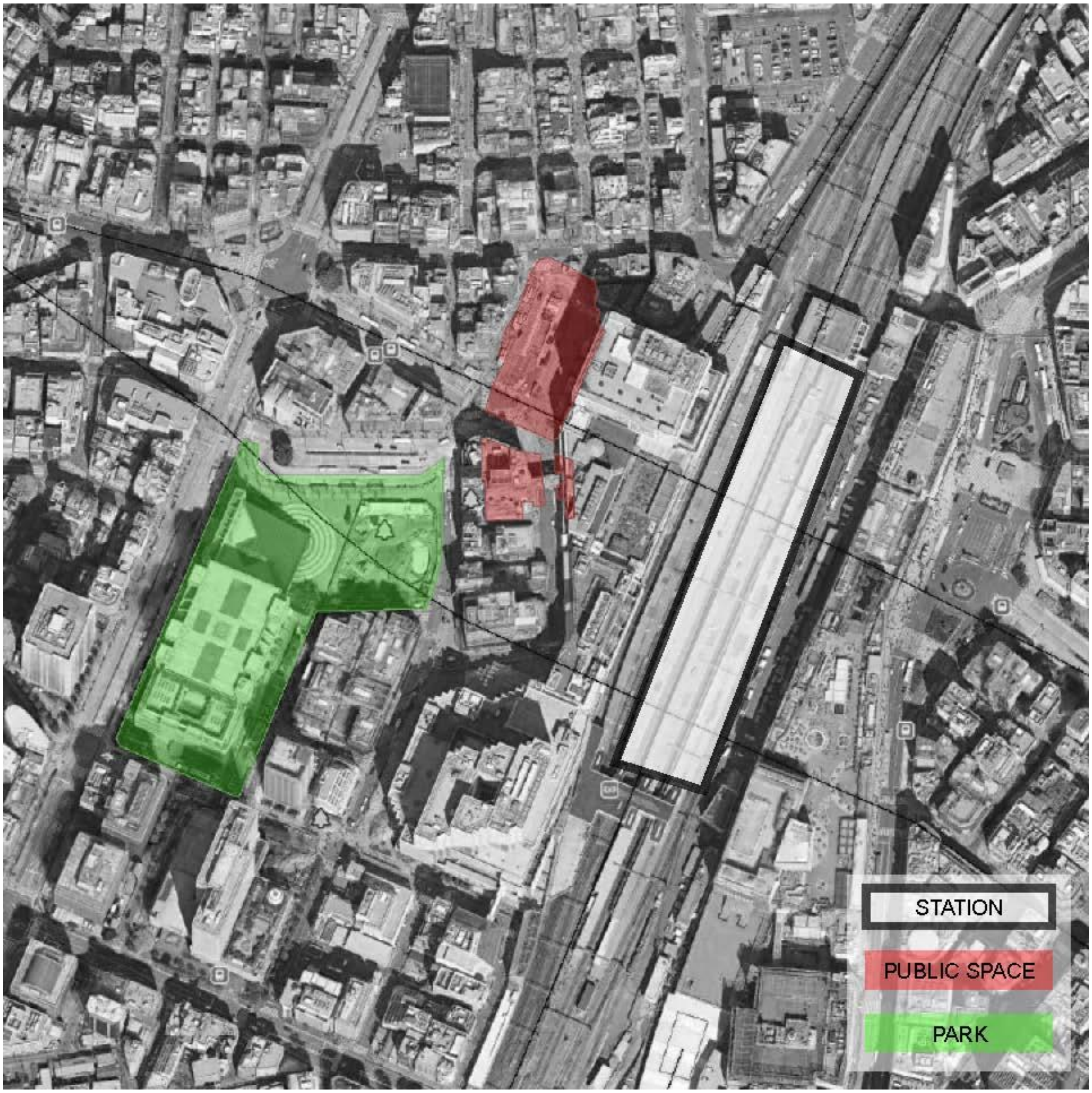
6. Shibuya Station diagram[2]



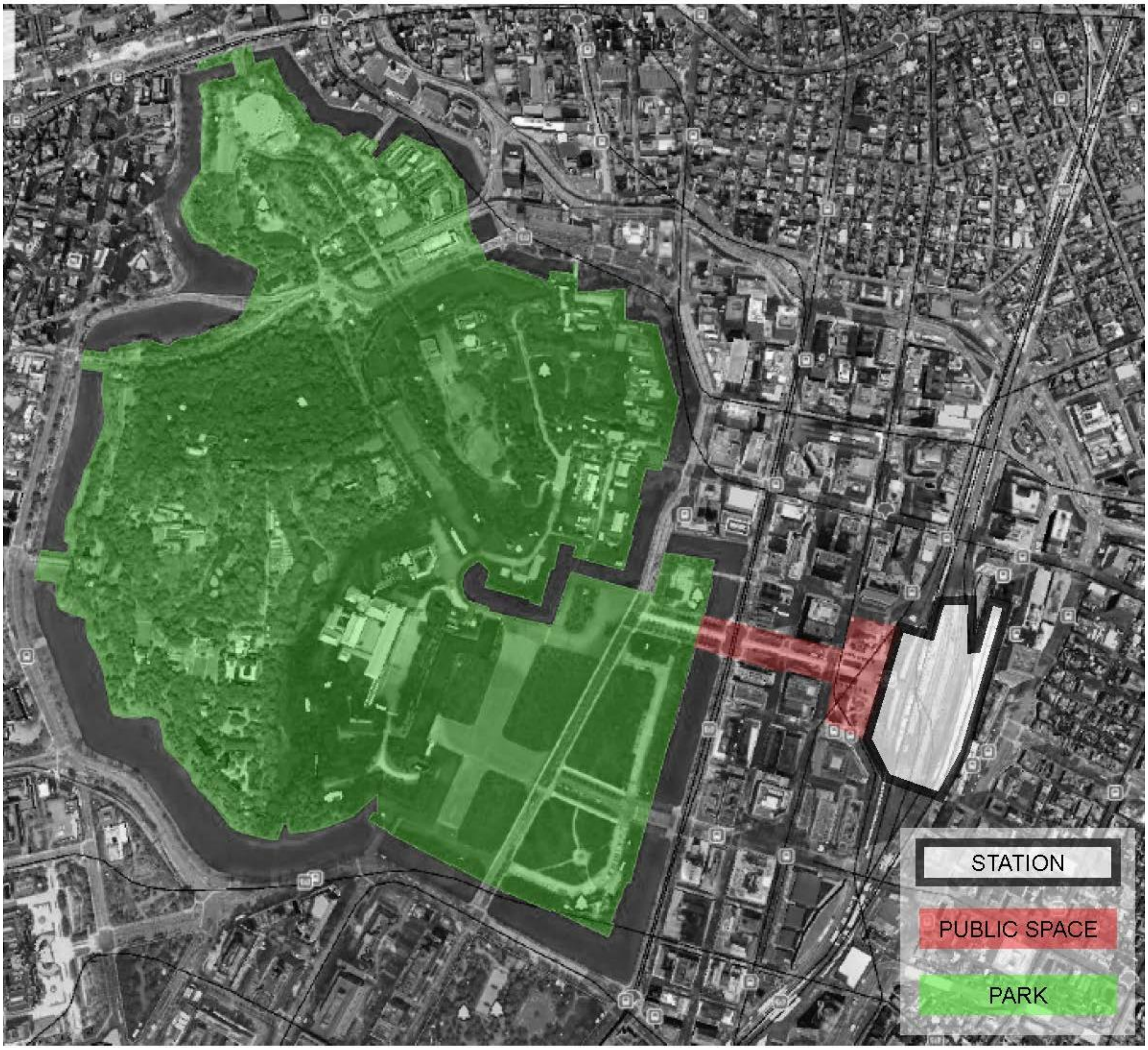
7. Shinjuku Station diagram[2]



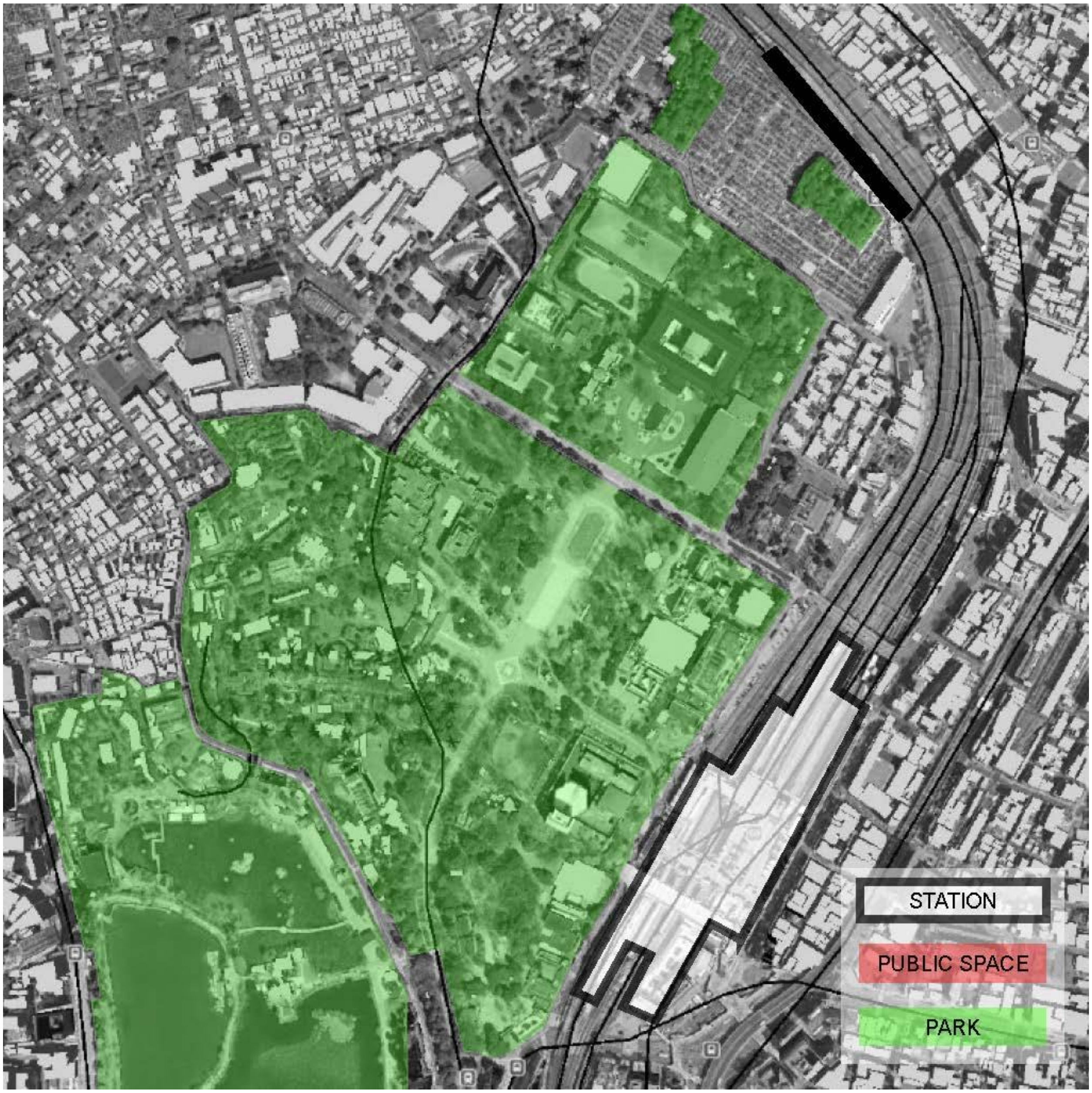
8. Shinagawa Station diagram[2]



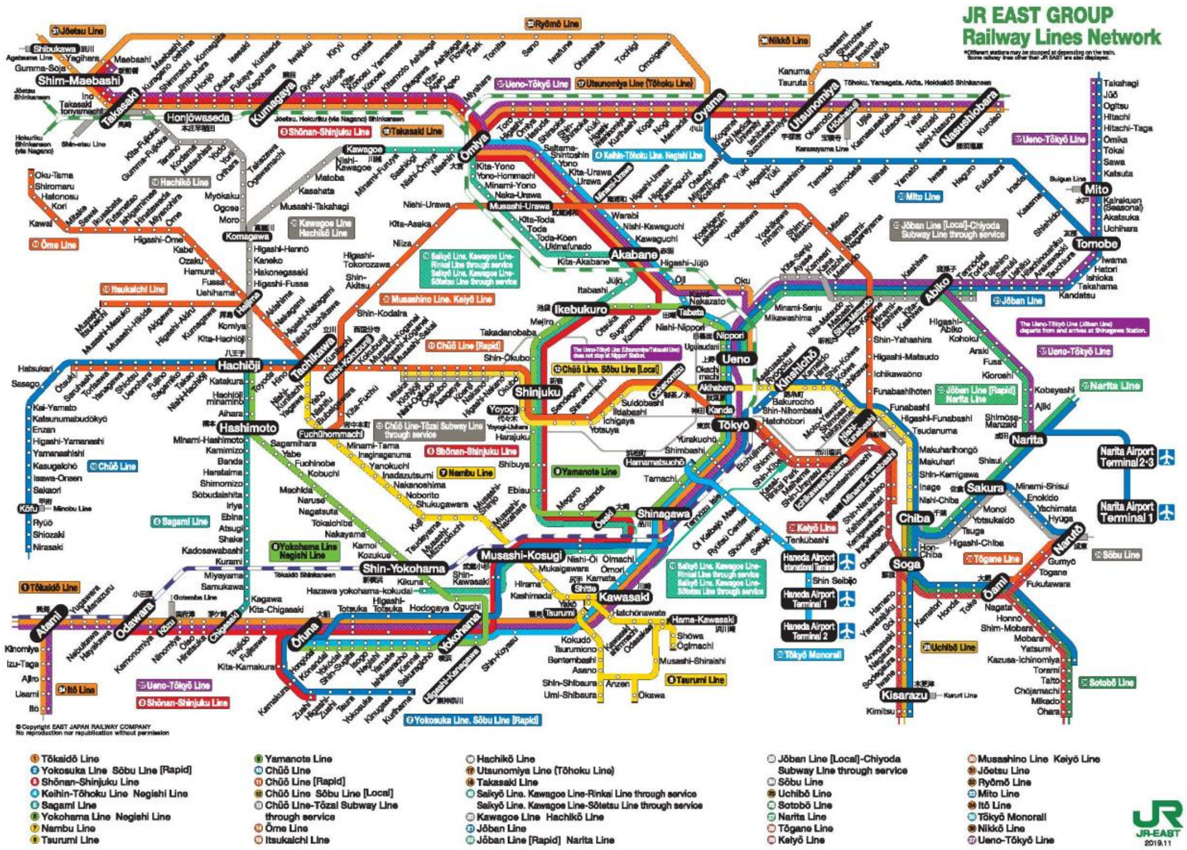
9. Ikebukuro Station diagram[2]



10. Tokyo Station diagram[2]



11. Ueno Station and Uguisudani Station diagram[2]



12. JR East Tokyo rail map 2020[3]

[3]"Guides & Info." JR. Accessed May 7, 2020. https://www.jreast.co.jp/e/downloads/.