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The Importance of Resilience in Japan's Critical Infrastructure: A Historiographical / Theoretical Perspective

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Abstract: The growth in the importance of resilience as an inherent quality of Japanese Critical Infrastructures observed throughout the last decades of the 20th century and the beginning of the 21st century directly affects the construction of systems capable of overcoming different types of threats. In this context, an axis of information was identified, constituted by the set of security - resilience - criticality, which remains explicit in the documents, public and private action plans whose study provides important data to the Historiography of the Present Time, since from its analysis emerge possible hypotheses that complement, from historiographical praxis, the hard qualitative and quantitative work done over the years by experts in the documentary and archival field.
Keywords: resilience, critical infrastructures, resilience, adaptation, security.

Introduction

The history of Japan has been characterized in the last century by the occurrence of various natural disasters that have had a significant impact on its infrastructure and its population in general. In fact, according to experts such as Yukihiro Izumi, a researcher at the Tokyo Institute of Technology, "Japan is one of the country's most prone to natural disasters in the world due to its geographical location and climatic conditions" (Izumi, 2019). In this context, Japanese critical infrastructures run the risk of being particularly vulnerable to adverse or catastrophic events, since their level of exposure to all kinds of disturbances in their critical systems is worryingly high.

Therefore, resilience in critical infrastructures, understood as the ability of an infrastructure to resist, adapt and recover from adverse situations and continue to function at an optimal level, has become a topic of great importance for the Japanese government and society. as a whole. As Kenji Watanabe, director of the Infrastructure Protection Division of the Ministry of Economy, Trade and Industry of Japan, points out, "resilience in critical infrastructures is essential to guarantee national security, the protection of life and property of people, and the maintenance of social well-being" (Watanabe, 2020).

In the current context, in which the scientific literature lacks mixed studies that address the concept of resilience in Critical Infrastructures, it is of great interest to carry out an exhaustive analysis of the different theoretical perspectives that address this issue. The objective of this approach is to establish a correlation between the three fundamental axes: criticality, resilience and security, with the purpose of complementing existing deterministic research, through both a quantitative and qualitative perspective. To achieve this end, the mixed and comparative method will be used as an essential tool for the reprocessing of deterministic data. This will make it possible to identify the quantifiable variables of the resilient critical infrastructure systems, in order to establish systemic relationships between the data obtained from the available material records. Consequently, it will be possible to confront the qualitative approaches with the quantifiable data and extract from this process an objective approach to the subject in question, with the purpose of complementing the information obtained through various research methods.

For this reason, this research aims to identify the main characteristics of Japanese critical infrastructures and their importance in the country's society and economy, analyze historical cases of natural disasters that have affected Japanese critical infrastructures, to identify vulnerabilities and challenges they face and evaluate the resilience strategies implemented in Japanese critical infrastructures, as a measure to improve their resilience and recovery capacity.

To carry out this analysis, a non-experimental panel-type design was used, which was applied longitudinally or evolutionarily to the subgroup of Japanese critical infrastructures developed over the last twenty years and that are part of the object of study. It should be taken into account, based on what was previously mentioned, that according to Hernández, Fernández and Baptista (2006):

> In a non-experimental study, no situation is built, but already existing situations are observed, not intentionally provoked in the research by the person who performs it. In non-experimental research, independent variables occur and it is not possible to manipulate them, there is no direct

> control over these variables, nor can they be influenced, because they have already happened, just like their effects. (p.205)

On the other hand, the use of a mixed approach has been preferred, integrating quantitative and qualitative variables, in order to approach the object of study from a systemic perspective.

According to Hernández, Fernández and Baptista (2006):

> The mixed approach is a process that collects, analyzes and links quantitative and qualitative data in the same study or a series of investigations to respond to a problem statement (...). Methods from the qualitative and quantitative approaches are used and may involve the conversion of quantitative data into qualitative data and vice versa (...). Also, the mixed approach can use the two approaches to answer different research questions of a problem statement. (p.755)

Regarding the techniques used, documentary research was used by applying the bibliographic systematization, the content analysis of the qualitative approach and the quantified textual analysis belonging to the field of the quantitative approach.

Finally, in order to contribute to a methodical and systematized development of the research, its content has been structured into four sections. In the first section "Critical Infrastructures: Definition, General Theoretical Elements and Japanese Conceptualizations" an exhaustive theoretical analysis of the constitutive elements of the Critical Infrastructures concept is carried out and various definitions provided by the Japanese academic community are examined in order to obtain an understanding. deeper into this concept. In the second section "Resilience in critical infrastructures: Definition and analysis of its relevance in today's Japan", the concept of resilience and its link to the field of Critical Infrastructures is analyzed, placing special emphasis on the evolution and development of this relationship in Japanese society. In the third section “Historical cases of resilience in Japanese critical infrastructures. Two paradigmatic examples”, the application of the concept of resilience in the context of Critical Infrastructures is examined through two highly relevant events: the Kobe earthquake in 1995 and the Tohoku earthquake in 2011. Finally, in the fourth section "Strategies and resilience measures in Japanese critical infrastructures" explores the different types of management, measures and actions aimed at improving the security, adaptation and response capacity of Critical Infrastructure systems that intervene in the development of Japanese society. In this way, an attempt is made to analyze the importance of resilience in Japanese critical infrastructures, based on the study of historical cases and the identification of adaptation and improvement strategies.

1. Critical infrastructures: Definition, general theoretical elements and Japanese conceptualizations.

Critical Infrastructures are essential elements in today's society, since they guarantee the correct functioning of various processes and systems, which are essential not only for the continuity and development of the global community but also for people's daily lives. Its study and protection are necessary to ensure the resilience and sustainability of society as a whole, since any failure or damage to these infrastructures could have unfavorable consequences for the well-being and safety of the population and for the various systems of which it is a part.

Delving into their study in order to favor their correct management, allows us to rigorously identify those theoretical elements that cross the different concepts of Critical Infrastructures, regardless of the social system in which they are inserted. In this sense, from a theoretical perspective, the essential elements that emerge through the process of defining Critical Infrastructures allow us to describe them as tangible and/or intangible systems that are crucial to maintain the functionality of the social fabric as a whole, being society its reason of existing. Encompassing its creation and development on various geopolitical scales.

This statement finds support in a variety of definitions provided by public and private actors who have addressed the issue over the past decades. A concrete example of the application of these theoretical elements is found in the definition of Critical Infrastructures provided in article 2.a of Directive 2008/114/EC of the Council of the European Union, according to which Critical Infrastructures are:

> (…) elements, systems or parts of them located in the Member States that are essential for the maintenance of vital social functions, health, physical integrity, security and the social and economic well-being of the population and whose disturbance or destruction would affect seriously to a Member State by not being able to maintain those functions.
> (Council of the European Union, 2008).

This definition highlights the importance of Critical Infrastructures for society and the need to adequately protect them to guarantee the safety and well-being of the population.

An additional example of applied theoretical analysis is evidenced in the measures adopted by the Australian government for the protection of Critical Infrastructures in the country, which resulted in the creation of the Critical Infrastructure Center in 2017. According to this center, the Critical infrastructures are:

> (...) physical facilities, supply chains, information and communication technologies and their networks, whose degradation, destruction or prolonged unavailability would have a significant impact on the social life or economic well-being of the nation. In addition, the Center highlights that these infrastructures also play an important role in the country's ability to carry out national defense and ensure national security.
> (ICC, 2017)

On the other hand, the definitions provided particularly by Japanese authors reflect the existence of these theoretical elements, placing emphasis not only on tangible systems, but also on intangible networks and systems essential for the functioning of society as a whole. In this context, authors such as Hikaru Yoshimura, maintain that Critical Infrastructures are "the set of facilities and equipment necessary to maintain fundamental social and economic functions, which, if they fail, could cause serious damage to life, health, security and the economy of society" (Yoshimura, H., 2006). On the other hand, Akio Saito defines Critical Infrastructures as "those essential facilities for society that are essential to maintain the life, safety and well-being of people, and whose collapse can cause significant damage to society" (Saito, A., 2008).

Finally, Kiyoshi Onishi describes Critical Infrastructure as "the systems and facilities necessary to maintain the essential functions of society, including the supply of energy, water, transportation, communications, finance, and health care services, and the collapse of which could cause serious damage to the life, safety and economy of society" (Onishi, K., 2010).

The previously exposed theoretical analysis reflects how in different types of systems, Critical Infrastructures include a wide variety of essential elements and networks for society as a whole, whose damage or destruction would have a significant impact on health, safety or economic well-being. and social of the population; highlighting in turn that the definition of critical infrastructures is not limited to physical elements, but also includes information and communication systems and technologies essential for the sustainability of critical functions within the aforementioned systems.

2. Resilience in critical infrastructures: Definition and analysis of its relevance in today's Japan

Resilience as a virtue or quality developed by various types of entities is a term that has gained great relevance in recent years, mainly due to the increasing importance that has been given to the capacity of systems, networks and individuals to adapt to radical changes and disturbances. In this sense, from a theoretical perspective, the concept of resilience can be understood as the ability of an entity to overcome the difficulties and challenges that arise throughout its development, applying such a concept to an important variety of contexts. This statement is reflected in various definitions, such as the one provided by the United States National Institute of Standards and Technology (NIST), for whom resilience is defined as "the ability to resist, absorb, adapt, and recover from adverse shocks, changes or failures" (NIST, 2015).

Resilience as a concept, not only implies the ability to resist and recover from an adverse event, but also the ability to adapt and learn from past situations in order to expand the limits of response to future critical events, thus becoming a quality of great relevance in environments exposed to constant changes and unpredictable disturbances.

In the specific context of Critical Infrastructures, resilience is essential to guarantee the safety and well-being of the population, since applied to this area, once acquired or developed, it guarantees the ability to resist and recover from adverse events, such as cyber attacks, floods, earthquakes, climatic deterioration, among others. In line with these theoretical statements, different entities such as the Department of Homeland Security of the United States, have argued that the resilience of Critical Infrastructures implies "the capacity of these infrastructures to withstand interruptions, recover quickly and continue operating at the level necessary to guarantee the security and economic and social well-being of the population" (DHS, 2015).

In the case of Japan, a country with a high exposure to natural disasters such as earthquakes, tsunamis and typhoons, the resilience of its Critical Infrastructures is essential to guarantee the safety and well-being of its population and the global economy. According to a report by the International Energy Agency (IEA), "Japan is one of the country's most vulnerable to interruptions in energy supply due to its high dependence on energy imports and its exposure to natural disasters" (IEA, 2020). In addition, resilience in transport and telecommunications infrastructures is essential to guarantee the continuity of the global supply chain, as

highlighted by Kyoto University professor Yasuyuki Todo, stating that "disruptions in transport infrastructure and communications can have cascading effects globally" (Todo, 2021).

Resilience also has an impact on Japan's national security and defense, as its critical infrastructures are potential targets for cyber and terrorist attacks. Both public and private bodies maintain that there is ongoing concern about terrorist attacks against critical Japanese infrastructure, particularly energy and transportation systems. Therefore, resilience in critical infrastructure is not only important to ensure the safety and well-being of the Japanese people and the global economy, but it is also crucial to protect Japan's national security against potential terrorist attacks.

3. Historical cases of resilience in Japanese critical infrastructures. Two paradigmatic examples

The 1995 Kobe earthquake, also known as the Great Hanshin-Awaji Earthquake, was one of the most devastating earthquakes in Japan's history. The magnitude 6.9 earthquake struck the Kobe region on January 17, 1995, killing more than 6,434 people. In addition to the damage to homes and buildings, critical infrastructure in the region, such as roads, bridges, and utilities, was also severely damaged.

However, the response of the authorities and the community to this catastrophic event highlighted the importance of resilience in Critical Infrastructures. Recovery efforts in Kobe focused on strengthening infrastructure to make it more resilient to natural disasters, as well as improving early warning systems to better prepare citizens for a future devastating event. The Kobe earthquake represented an important wake-up call to the government and private companies, who began to consider the resilience of Critical Infrastructures as an essential component of the development of preventive policies. Since then, measures such as the reinforcement of bridges and roads, the construction of earthquake-proof buildings and the improvement of water and electricity supply systems have been implemented to ensure that Critical Infrastructures can withstand future catastrophic events.

On the other hand, the 2011 Tohoku earthquake and tsunami was one of the largest and most destructive disasters in Japanese history. The magnitude 9.0 earthquake, which occurred on March 11, 2011, triggered a massive tsunami that devastated the northeast coast of Japan. The natural disaster caused the death of more than 15,000 people, damaged nearly half a million buildings and left more than 300,000 homeless. In addition, critical infrastructure in the region suffered serious damage. The response to the calamity caused by the Tohoku earthquake highlighted the importance of resilience as a necessary quality of Critical Infrastructures. Different public and private organizations in Japan emphasized the relevance of resilience, arguing that, although natural disasters cannot be fully avoided, the resilience of the infrastructures on which society depends can be optimized through proper planning. Since then, different initiatives have been launched with the aim of reinforcing the resilience of Japan's Critical Infrastructures, such as the construction of dikes and containment barriers, the installation of early warning systems, and the consolidation of safety networks. power and communications to ensure its ability to withstand future disasters.

In this context, some authors such as Keiji Miyamoto, a professor at Kobe University, pointed out that "the Tohoku earthquake demonstrated the need for a resilience approach in the planning and construction of critical infrastructures, such as nuclear power plants. Resilience, it is not only the ability to recover from a disaster, but also the ability to anticipate and prevent future disasters" (Miyamoto, 2012). In turn, Takeshi Iwata, a professor at Tohoku University, said that "after the Tohoku earthquake, it has become clear that stricter resilience measures are needed in the construction of buildings and critical infrastructures. Engineers and architects should consider not only the minimum-security requirements, but also the possible disaster situations that may occur" (Iwata, 2011).

4. Resilience strategies and measures in Japanese critical infrastructures

In order to ensure the well-being and safety of society in anticipation of possible future adverse events, Japan has implemented various policies and regulations to promote resilience in its Critical Infrastructures, focusing its efforts on taking measures based on the lessons learned from the natural catastrophes that the nation has experienced in recent decades.

In 2005, the Japanese government established the "Critical Infrastructure Resilience Basic Act" promulgated on May 6, 2005, which urged companies and government agencies to identify and assess the risks of natural disasters, in its Critical Infrastructures, in order to take measures to reduce these risks. The law also established the obligation of companies to maintain a crisis management system and to inform the competent authorities about their preparation protocols for possible natural disasters.

Experts such as Hiroshi Takeyama, former director general of the Japan Disaster Management Agency, argued that, "The Critical Infrastructure Resilience Basic Law is a comprehensive law that establishes a basic policy to improve the resilience of critical infrastructure in Japan. The law is an important step towards creating a society resilient to natural disasters and other hazards" (Takeyama, 2007).

Additionally, in 2013, Japan established the "Action Plan for Promoting Critical Infrastructure Resilience," favoring specific measures to enhance resilience in key areas such as energy, communications, transportation, and healthcare.

The plan, a continuation of the "Basic Law on Critical Infrastructure Resilience" promulgated in 2005, included a series of concrete objectives and strategies to be adopted by the Japanese government to strengthen the resilience of its Critical Infrastructures. These included the identification of risks and vulnerabilities, the improvement of the information and communication infrastructure, the training of specialized personnel in resilience and the promotion of cooperation and collaboration between stakeholders. As crisis management expert and Waseda University professor Takeshi Komino points out, "Japan has learned the lesson of past natural disasters and has established policies and regulations to ensure the resilience of its critical infrastructure" (Komino, 2021).

At present, Japan has adopted various technologies with the aim of improving the resilience of its critical infrastructures, reducing the risk of interruption of essential services during a natural disaster, and accelerating post-disaster recovery. Among the most outstanding technologies is the earthquake early warning system, developed by the Japan Meteorological Agency, which allows citizens to receive a pre-earthquake alert so they can seek shelter and prepare for the event. This system also facilitates the safe interruption of public transport services and other critical services. The professor of seismology at the University of Hokkaido, Hiroaki Negishi, has highlighted in this regard that "Japan has one of the most advanced earthquake early warning systems in the world, which has helped save many lives" (Negishi, 2018). Additionally, the implementation of renewable energy technologies, such as solar and wind energy, and micro generation, have allowed the provision of alternative and redundant energy sources in the event of an interruption in the electrical network. In this sense, the professor of energy policy at the University of Tokyo, Masakazu Toyoda, has affirmed that "renewable energy, particularly solar and wind energy, can play an important role in the resilience of Critical Infrastructures, since it provides an alternative and redundant source of energy in the event of interruptions in the electrical network" (Toyoda, 2018). On the other hand, the application of artificial intelligence technologies and data analysis have contributed to crisis management and decision-making in emergency situations. Real-time data analysis has the ability to identify areas affected by a natural disaster and help authorities mobilize resources effectively. In this regard, the professor of disaster management at Tohoku University, Shuji Tamura, has pointed out that "AI and data analysis can improve the ability of crisis management organizations to quickly identify affected areas and coordinate efforts." rescue and recovery" (Tamura, 2021).

Finally, risk assessment is a fundamental factor to determine the probability that a Critical Infrastructure will be affected by an adverse event, as well as to identify the necessary prevention and mitigation measures. In that sense, the construction of structures resistant to earthquakes and tsunamis is one of the most common prevention measures in Japan. According to Miyajima et al. (2019), building regulations in Japan are among the most stringent in the world and focus on ensuring structural safety and seismic resistance, including specific requirements for the location, height, and resistance of buildings and critical infrastructure.

Risk assessment is also essential to determine the necessary mitigation measures. According to Yashiro et al. (2019), in Japan, risk analyzes are carried out at different levels, from the national government to companies and local communities, in order to assess the possible impacts of adverse events on Critical Infrastructures and to identify the necessary measures to minimize damage and speed recovery.

Final thoughts

The long and painful history of natural disasters in Japan has led the country to be one of the main drivers of resilience in various systems and networks. The survival of the country depends on the functionality of its Critical Infrastructures, such as energy, transport and telecommunications, in moments of crisis. Therefore, resilience, understood as the ability to quickly recover after a stressful event, has become a critical priority for Japan in managing its critical infrastructure. Through rigorous policies and regulations, Japan has established a culture of resilience in the management of its infrastructures, evidenced in the development of innovative solutions and advanced technologies and in the importance given to risk assessment and prevention measures, essential to reduce the risks of natural disasters on Critical Infrastructures. Case studies have shown that resilience can be effective in reducing damage and speedy recovery after natural disasters. The Kobe and Tohoku earthquakes are two eloquent examples of how resilience has allowed the rapid recovery of Critical Infrastructures after different natural disasters.

In terms of implications, it is essential to continue exploring and developing technologies and solutions that foster the resilience of Critical Infrastructure in Japan. In addition, it is of the utmost importance that policies and regulations continue to be updated to address emerging risks and threats. Regarding the recommendations for future research, it is suggested to deepen the analysis of the economic and social effects of natural disasters in Japan, as well as the importance of the resilience of Critical Infrastructures to mitigate these

effects. Likewise, it would be appropriate to investigate the potential of applying innovative technologies, such as artificial intelligence and the Internet of Things, in optimizing resilience.

In short, the resilience of Japan's critical infrastructure has been vital in dealing with the natural disasters that have struck the country throughout its history. The adaptation and recovery of these infrastructures has minimized the impacts of disasters, has preserved the safety and quality of life of the population, and has guaranteed the continuity of essential services. However, it is important to highlight that resilience is not a permanent solution, but a dynamic process of improvement and adaptation to the changes and challenges that society faces. Therefore, it is necessary to continue implementing policies, technologies and prevention measures to further strengthen the resilience of Critical Infrastructures and guarantee the protection of the population. Japan has been a model to show how resilience can be implemented and improved over time, which should be a lesson for other countries facing similar challenges.

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