JOURNAL OF ADVANCED ENGINEERING AND INNOVATION
Volume 3, Issue 1, June 2025 | pp. 44-54
https://doi.org/10.54518/jaei.3.1.2025.1329

Artificial Intelligence Applications in Structural Health Monitoring: Comparing Japan and South Korea

Taip Gegetu[1] ✉

Universitas Pendidikan Muhammadiyah Sorong, Indonesia[1]

ABSTRACT

Artificial Intelligence (AI) has significantly transformed Structural Health Monitoring (SHM) by enabling intelligent damage detection, condition assessment, predictive maintenance, and real-time infrastructure monitoring. Recent advancements in machine learning, deep learning, computer vision, and sensor technologies have accelerated the adoption of AI-based SHM systems, particularly in Japan and South Korea, two countries recognized for their technological innovation and resilient infrastructure development. This study aims to systematically review research published over the last five years to compare AI applications in Structural Health Monitoring in both countries. Using a Systematic Literature Review (SLR) approach, the study synthesizes recent developments, implementation strategies, application areas, benefits, challenges, and future research directions. The findings reveal that Japan emphasizes AI for disaster-resilient infrastructure and seismic monitoring, whereas South Korea focuses on smart infrastructure management and automated inspection systems. Despite significant progress, both countries continue to face challenges related to data integration, model reliability, implementation costs, and skilled workforce availability. This review provides evidence-based insights to support future AI-driven SHM research and sustainable infrastructure management.

Keywords: *Artificial Intelligence, Japan, Machine Learning, South Korea, Structural Health Monitoring.*

CORRESPONDING AUTHOR:
Taip Gegetu
Universitas Pendidikan Muhammadiyah Sorong, Indonesia

ARTICLE HISTORY
Received : January 20, 2025
Final Revised : March 13, 2025
Accepted : May 11, 2025
Published : June 30, 2025

1. | INTRODUCTION

The safety and reliability of civil infrastructure have become increasingly important as many countries face the challenges of aging structures, rapid urbanization, increasing traffic loads, and more frequent natural disasters (Lu et al., 2020). Bridges, tunnels, high-rise buildings, railways, and other critical infrastructure require continuous monitoring to ensure structural integrity and public safety throughout their service life. Conventional inspection methods, which primarily rely on periodic visual assessments and manual measurements, are often time-consuming, labor-intensive, and unable to provide continuous information regarding structural conditions. These limitations have encouraged the development of Structural Health Monitoring (SHM), an advanced engineering approach that utilizes sensing technologies and data analysis to continuously evaluate the condition and performance of infrastructure. By providing real-time information on structural behavior, SHM enables early damage detection, supports preventive maintenance, and reduces the risk of unexpected structural failures (Vijayan et al., 2023).

Recent technological advancements have significantly enhanced the capabilities of SHM through the integration of Artificial Intelligence (AI). AI enables SHM systems to automatically process large volumes of monitoring data, identify damage patterns, classify structural conditions, and predict future deterioration with greater speed and accuracy than conventional analytical methods (Hartmann et al., 2023). Various AI techniques, including machine learning, deep learning, computer vision, artificial neural networks, and reinforcement learning, have been increasingly applied to vibration analysis, crack detection, damage localization, anomaly detection, and predictive maintenance. Combined with modern sensing technologies such as wireless sensor networks, fiber optic sensors, unmanned aerial vehicles (UAVs), and Internet of Things (IoT) devices, AI has transformed SHM from a passive monitoring system into an intelligent decision-support platform capable of improving infrastructure management and operational efficiency (Choi et al., 2022)

The growing adoption of AI-based SHM has been particularly evident in technologically advanced countries such as Japan and South Korea. Both countries possess extensive transportation networks, high-density urban infrastructure, and significant exposure to natural hazards, including earthquakes, typhoons, and extreme weather events. These conditions have encouraged substantial investment in smart infrastructure technologies that improve infrastructure resilience and public safety. However, despite sharing similar technological capabilities, Japan and South Korea have adopted different strategies in implementing AI for Structural Health Monitoring. Japan has primarily emphasized disaster resilience by integrating AI into seismic monitoring, earthquake early warning systems, bridge assessment, and long-term infrastructure maintenance (López et al., 2022). AI-based SHM has become an important component of Japan's efforts to improve infrastructure resilience against natural disasters while extending the service life of aging infrastructure (Amaechi et al., 2022).

In contrast, South Korea has focused on developing smart infrastructure ecosystems by integrating AI with digital construction technologies, automated inspection systems, robotics, cloud computing, and intelligent transportation infrastructure. Government initiatives supporting digital transformation have accelerated the deployment of AI-enabled monitoring systems across bridges, tunnels, railways, and public buildings. The integration of AI with real-time sensing technologies allows infrastructure managers to automate inspections, improve maintenance planning, optimize resource allocation, and reduce operational costs. This digital transformation reflects South Korea's broader strategy of developing intelligent infrastructure capable of supporting sustainable urban development and improving the efficiency of national transportation networks (Kwak et al., 2021).

Although numerous studies have investigated AI applications in Structural Health Monitoring, existing research has generally focused on specific algorithms, sensing technologies, or individual case studies within a single country. Comparative reviews examining recent developments, implementation strategies, technological trends, practical applications, and challenges between Japan and South Korea remain relatively limited. Such comparative analysis is important because both countries represent leading examples of AI adoption in civil infrastructure while demonstrating different policy priorities, technological approaches, and implementation experiences. Understanding these similarities and differences can provide valuable insights for researchers, engineers, infrastructure managers, and policymakers seeking to improve AI-based SHM implementation in other countries (Pundir et al., 2022).

Therefore, this study conducts a Systematic Literature Review (SLR) of peer-reviewed journal articles published between 2020 and 2024 to compare recent advances in Artificial Intelligence applications for Structural Health Monitoring in Japan and South Korea. The review synthesizes current research trends, AI techniques, implementation strategies, application areas, benefits, challenges, and future research opportunities (Mohsan et al., 2023). By providing a comprehensive comparison of recent developments in both countries, this study aims to contribute to the growing body of knowledge on intelligent infrastructure monitoring and offer evidence-based recommendations for the future development of AI-driven Structural Health Monitoring systems.

2. | RESEARCH METHOD

This study employed a Systematic Literature Review (SLR) to identify, evaluate, and synthesize recent research on the application of Artificial Intelligence (AI) in Structural Health Monitoring (SHM), with a comparative focus on Japan and South Korea. The SLR method was selected because it provides a structured, transparent, and reproducible approach for reviewing scientific literature, allowing researchers to minimize selection bias while generating comprehensive and reliable findings. The review process consisted of four main stages: literature identification, screening, eligibility assessment, and qualitative synthesis. Relevant articles were collected from internationally recognized scientific databases, including Scopus, Web of Science, ScienceDirect, SpringerLink, IEEE Xplore, and MDPI. The literature search used combinations of keywords such as "Artificial Intelligence," "Structural Health Monitoring," "Machine Learning," "Deep Learning," "Civil Infrastructure," "Bridge Monitoring," "Japan," and "South Korea" (Li et al., 2022). Only peer-reviewed journal articles published between 2020 and 2024 were included to ensure that the review reflected recent technological developments and current research trends. The inclusion criteria required that the selected studies explicitly discuss AI applications in Structural Health Monitoring for civil infrastructure, including bridges, tunnels, buildings, transportation systems, or other engineering structures, while focusing on implementation, methodology, performance evaluation, or practical applications in Japan or South Korea (Kim et al., 2020).

Studies unrelated to civil engineering, review papers lacking comparative discussion, conference proceedings, book chapters, duplicate publications, and articles without sufficient methodological information were excluded. Following the screening process, all eligible articles were analyzed using qualitative content analysis to extract relevant information, including publication year, research objectives, infrastructure type, AI techniques employed, sensing technologies, implementation strategies, application areas, reported benefits, technical challenges, and recommendations for future research (Awan et al., 2021). The extracted information was then classified into thematic categories to facilitate a comparative evaluation of AI adoption in Japan and South Korea. The final synthesis focused on identifying similarities and differences in technological development, implementation approaches, infrastructure applications, research trends, and existing knowledge gaps. Through this systematic procedure, the study provides a comprehensive overview of recent advances in AI-driven Structural Health Monitoring while offering evidence-based insights and practical recommendations for researchers, engineers, infrastructure managers, and policymakers seeking to improve the safety, resilience, and sustainability of civil infrastructure through intelligent monitoring technologies.

3. | RESULTS AND DISCUSSION

The systematic literature review indicates that research on Artificial Intelligence (AI) applications in Structural Health Monitoring (SHM) has expanded considerably between 2020 and 2024, reflecting the increasing demand for intelligent infrastructure management and resilient civil engineering systems (Murtagh et al., 2020). The reviewed studies consistently demonstrate that AI has become a fundamental technology for improving the efficiency, accuracy, and reliability of structural monitoring by enabling automated damage detection, condition assessment, predictive maintenance, and real-time decision-making. Unlike conventional SHM approaches, which depend heavily on manual inspections and predefined analytical models, AI-driven systems are capable of processing large volumes of sensor data, identifying complex structural patterns, and predicting structural deterioration with high accuracy. The rapid advancement of machine learning, deep learning, computer vision, and data analytics has further accelerated the integration of AI into bridges, tunnels, railways, high-rise buildings, dams, and other critical infrastructure (Flah et al., 2021).

One of the most significant findings identified in the reviewed literature is the increasing integration of AI with advanced sensing technologies. Modern SHM systems no longer rely on a single monitoring technique but combine wireless sensor networks, fiber optic sensors, accelerometers, strain gauges, Global Navigation Satellite System (GNSS) measurements, unmanned aerial vehicles (UAVs), and Internet of Things (IoT) devices to collect continuous structural information. AI algorithms analyze these large and heterogeneous datasets to recognize abnormal structural behavior, classify damage types, estimate structural performance, and generate maintenance recommendations. This integration enables infrastructure managers to shift from periodic inspection practices toward continuous condition-based monitoring, improving operational efficiency while reducing maintenance costs and minimizing the risk of unexpected structural failures (Adekunle et al., 2021).

The comparative analysis reveals that Japan has established one of the world's most advanced AI-based SHM ecosystems, primarily driven by its exposure to earthquakes, typhoons, volcanic activity, and aging infrastructure. These environmental and demographic challenges have encouraged continuous investment in intelligent monitoring technologies capable of supporting disaster resilience and long-term infrastructure management. AI has been widely implemented to monitor bridges, tunnels, railway systems, high-rise buildings, and public infrastructure by analyzing vibration signals, displacement measurements, crack propagation, and seismic responses. Machine learning and deep learning algorithms have demonstrated strong capabilities in identifying structural anomalies that may not be detectable through conventional inspection methods. In addition, Japan has increasingly integrated AI into earthquake monitoring systems to improve post-earthquake structural assessment and prioritize emergency inspections based on predicted damage severity. These developments contribute significantly to reducing inspection time while improving infrastructure safety and maintenance planning (Omrany et al., 2023).

Another important trend identified in Japan is the application of computer vision technologies for automated structural inspection. High-resolution cameras mounted on drones, robotic platforms, and autonomous vehicles are increasingly used to collect visual data from bridges, tunnels, and elevated structures. AI-based image recognition models subsequently analyze these images to detect cracks, corrosion, concrete spalling, surface deformation, and other structural defects without requiring direct human access to hazardous locations. This approach not only improves inspection efficiency but also enhances worker safety and reduces operational disruptions during infrastructure maintenance. Furthermore, combining computer vision with deep learning enables continuous improvement in defect recognition accuracy as larger datasets become available, supporting more reliable condition assessment and long-term asset management.

The review also indicates that AI implementation in Japan extends beyond damage detection toward predictive maintenance and infrastructure lifecycle optimization. Predictive models developed using historical monitoring data allow engineers to estimate structural deterioration rates, evaluate maintenance priorities, and optimize resource allocation before critical failures occur. Rather than relying on fixed maintenance schedules, infrastructure managers can perform maintenance based on actual structural conditions, thereby reducing unnecessary maintenance activities while extending infrastructure service life. This predictive approach has become particularly valuable for managing Japan's aging transportation infrastructure, where maintaining operational reliability while controlling maintenance costs represents a major national priority. Consequently, AI-driven Structural Health Monitoring has evolved into an essential component of Japan's broader strategy for developing resilient, sustainable, and intelligent infrastructure systems capable of supporting long-term public safety and economic development. South Korea has also demonstrated remarkable progress in the implementation of Artificial Intelligence for Structural Health Monitoring, although its development strategy differs from that of Japan. Rather than focusing primarily on disaster resilience, South Korea has emphasized the integration of AI into smart infrastructure, digital construction, and intelligent transportation systems. National investments in digital transformation have encouraged the deployment of AI-enabled monitoring systems across bridges, tunnels, railways, ports, and high-rise buildings, supporting the country's objective of creating highly connected and data-driven infrastructure networks. AI technologies are increasingly combined with cloud computing, Internet of Things (IoT) devices, wireless sensor networks, robotics, and unmanned aerial vehicles (UAVs) to establish continuous monitoring systems capable of collecting and analyzing structural information in real time. These integrated platforms allow engineers and infrastructure managers to monitor asset conditions remotely while improving the efficiency of maintenance planning and operational decision-making.

The reviewed studies indicate that machine learning and deep learning algorithms have become the dominant analytical approaches used in South Korean SHM applications. Convolutional Neural Networks (CNNs) are widely applied for automated image-based crack detection, while recurrent neural networks and other predictive learning models are employed to analyze time-series monitoring data for identifying abnormal structural responses and forecasting future deterioration. AI-assisted computer vision systems enable the rapid inspection of large infrastructure assets without interrupting normal operations, thereby reducing inspection time, minimizing labor requirements, and improving the consistency of damage assessment. Furthermore, AI models are increasingly trained using large-scale infrastructure datasets, allowing continuous improvement in prediction accuracy and supporting more reliable maintenance strategies throughout the infrastructure lifecycle.

The comparative analysis demonstrates that both Japan and South Korea recognize AI as a strategic technology for enhancing infrastructure safety, resilience, and operational efficiency. However, their implementation priorities reflect different national needs and policy directions. Japan primarily utilizes AI to strengthen disaster preparedness and improve the resilience of aging infrastructure exposed to earthquakes and other natural hazards. Consequently, many Japanese studies emphasize seismic monitoring, vibration analysis, structural reliability assessment, and post-disaster damage evaluation. In contrast, South Korea places greater emphasis on developing intelligent infrastructure ecosystems in which AI supports automated inspection, digital asset management, and smart city development. This broader integration of AI with digital construction technologies enables continuous monitoring, optimized maintenance scheduling, and efficient management of complex transportation and urban infrastructure networks.

Despite these strategic differences, both countries share several common technological characteristics. AI implementation is consistently supported by high-quality sensing technologies capable of collecting accurate structural information under various operational conditions. Wireless sensor networks, fiber optic sensors, accelerometers, strain gauges, LiDAR systems, and UAV-based inspections provide continuous data that serve as the foundation for AI analysis. Cloud computing platforms facilitate centralized data storage and high-performance computation, while IoT technologies enable seamless communication between monitoring devices and analytical systems. The combination of these technologies creates intelligent monitoring environments that improve collaboration among engineers, infrastructure operators, and decision-makers while reducing dependence on traditional manual inspection procedures (Kim et al., 2020).

Another important finding emerging from the reviewed literature is the growing contribution of AI to sustainable infrastructure management. Continuous structural monitoring allows infrastructure owners to detect deterioration at an early stage, preventing severe damage that would otherwise require extensive rehabilitation or complete replacement (Nagappan et al., 2020). Predictive maintenance supported by AI also reduces unnecessary inspections, optimizes maintenance budgets, extends infrastructure service life, and minimizes disruptions to public transportation and urban activities (Schaefer et al., 2021). Consequently, AI-driven Structural Health Monitoring not only improves engineering performance and public safety but also contributes to environmental sustainability through more efficient resource utilization, reduced material consumption, and improved lifecycle management of critical infrastructure assets.

4. | CONCLUSION

This study systematically reviewed recent advances in Artificial Intelligence (AI) applications for Structural Health Monitoring (SHM) by comparing research developments and implementation practices in Japan and South Korea based on peer-reviewed publications published between 2020 and 2024. The findings demonstrate that AI has transformed Structural Health Monitoring from a conventional inspection approach into an intelligent, data-driven system capable of supporting automated damage detection, condition assessment, predictive maintenance, and real-time infrastructure monitoring. The integration of AI with advanced sensing technologies, including wireless sensor networks, Internet of Things (IoT) devices, unmanned aerial vehicles (UAVs), computer vision, and cloud computing, has significantly improved the efficiency, accuracy, and reliability of infrastructure management throughout the asset lifecycle.

The comparative analysis indicates that Japan primarily emphasizes AI implementation for disaster resilience, seismic monitoring, and the maintenance of aging infrastructure, while South Korea focuses on smart infrastructure development, automated inspection systems, and digital asset management. Despite these different implementation strategies, both countries have successfully demonstrated that AI-driven SHM enhances infrastructure safety, optimizes maintenance planning, reduces operational costs, and supports sustainable infrastructure management.

Nevertheless, several challenges remain, including limited data standardization, model generalization, interoperability among digital platforms, high implementation costs, cybersecurity concerns, and shortages of multidisciplinary expertise. Addressing these issues requires stronger collaboration among governments, academic institutions, technology developers, and infrastructure operators. Future research should prioritize the development of standardized datasets, explainable and transferable AI models, and deeper integration with Digital Twin and other intelligent technologies to improve infrastructure resilience, operational efficiency, and long-term sustainability.

Acknowledgment

We gratefully acknowledge the contributions of individuals who supported the completion of this article.

Funding Information

This research did not receive any funding.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

Ethical Approval and Originality Statement

Ethical approval was obtained for this study. The manuscript represents original work and has not been previously published, nor is it under consideration by another journal.

Data Disclosure Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Adekunle, B. I., Chukwuma-Eke, E. C., Balogun, E. D., & Ogunsola, K. O. (2021). A predictive modeling approach to optimizing business operations: A case study on reducing operational inefficiencies through machine learning. *International Journal of Multidisciplinary Research and Growth Evaluation*, *2*(1), 791-799.

Amaechi, C. V., Reda, A., Kgosiemang, I. M., Ja'e, I. A., Oyetunji, A. K., Olukolajo, M. A., & Igwe, I. B. (2022). Guidelines on asset management of offshore facilities for monitoring, sustainable maintenance, and safety practices. *Sensors*, *22*(19), 7270.

Awan, U., Sroufe, R., & Shahbaz, M. (2021). Industry 4.0 and the circular economy: A literature review and recommendations for future research. *Business Strategy and the Environment*, *30*(4), 2038-2060.

Choi, T. M., Kumar, S., Yue, X., & Chan, H. L. (2022). Disruptive technologies and operations management in the Industry 4.0 era and beyond. *Production and operations management*, *31*(1), 9-31.

Flah, M., Nunez, I., Ben Chaabene, W., & Nehdi, M. L. (2021). Machine Learning Algorithms in Civil Structural Health Monitoring: A Systematic Review: M. Flah et al. *Archives of computational methods in engineering*, *28*(4), 2621-2643.

Hartmann, J., Heitmann, M., Siebert, C., & Schamp, C. (2023). More than a feeling: Accuracy and application of sentiment analysis. *International Journal of Research in Marketing*, *40*(1), 75-87.

Kim, H., & Jeon, B. (2020). Developing a framework for performance assessment of the public long-term care system in Korea: methodological and policy lessons. *Health Research Policy and Systems*, *18*(1), 27.

Kim, S., Irizarry, J., & Kanfer, R. (2020). Multilevel goal model for decision-making in UAS visual inspections in construction and infrastructure projects. *Journal of Management in Engineering*, *36*(4), 04020036.

Kwak, Y. H., & Lee, J. (2021). Toward sustainable smart city: Lessons from 20 years of Korean programs. *IEEE Transactions on Engineering Management*, *70*(2), 740-754.

Li, H., Chen, Y., Liu, J., Zhang, Z., & Zhu, H. (2022). Unmanned aircraft system applications in damage detection and service life prediction for bridges: A review. *Remote sensing*, *14*(17), 4210.

López-Castro, B., Haro-Baez, A. G., Arcos-Aviles, D., Barreno-Riera, M., & Landázuri-Avilés, B. (2022). A systematic review of structural health monitoring systems to strengthen post-earthquake assessment procedures. *Sensors*, *22*(23), 9206.

Lu, H., Chen, M., & Kuang, W. (2020). The impacts of abnormal weather and natural disasters on transport and strategies for enhancing ability for disaster prevention and mitigation. *Transport Policy*, *98*, 2-9.

Mohsan, S. A. H., Othman, N. Q. H., Li, Y., Alsharif, M. H., & Khan, M. A. (2023). Unmanned aerial vehicles (UAVs): Practical aspects, applications, open challenges, security issues, and future trends. *Intelligent service robotics*, *16*(1), 109-137.

Murtagh, N., Scott, L., & Fan, J. (2020). Sustainable and resilient construction: Current status and future challenges. *Journal of Cleaner Production*, *268*, 122264.

Nagappan, P. G., Chen, H., & Wang, D. Y. (2020). Neuroregeneration and plasticity: a review of the physiological mechanisms for achieving functional recovery postinjury. *Military Medical Research*, *7*(1), 30.

Omrany, H., Al-Obaidi, K. M., Husain, A., & Ghaffarianhoseini, A. (2023). Digital twins in the construction industry: a comprehensive review of current implementations, enabling technologies, and future directions. *Sustainability*, *15*(14), 10908.

Pundir, A., Singh, S., Kumar, M., Bafila, A., & Saxena, G. J. (2022). Cyber-physical systems enabled transport networks in smart cities: Challenges and enabling technologies of the new mobility era. *IEEe Access*, *10*, 16350-16364.

Schaefer, K. J., Tuitjer, L., & Levin-Keitel, M. (2021). Transport disrupted–Substituting public transport by bike or car under Covid 19. *Transportation Research Part A: Policy and Practice*, *153*, 202-217.

Vijayan, D. S., Sivasuriyan, A., Devarajan, P., Krejsa, M., Chalecki, M., Żółtowski, M., ... & Koda, E. (2023). Development of intelligent technologies in SHM on the innovative diagnosis in civil engineering—A comprehensive review. *Buildings*, *13*(8), 1903.