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“Technical Research and Development for Road Policy Quality Improvement” Study Summary

No.	Title	Principal Researcher
No.2022-3	Technical Research and Development on the Deepening of Backcast Road Policies Based on Statistical Asset Management Methods	Osaka Univ. Prof. Kiyoyuki Kaito

This research develops methodologies to enhance asset management and support/deepen backcast road policies through the integration of asset management with 1) deterioration attribute information, 2) EBPM, and 3) risk management.

1. Backgrounds and Objects

The development of hardware technology aimed at data collection for the maintenance and management of road infrastructure has been remarkable, leading to the acquisition of a vast amount of data from the field. In light of this situation and the future prospects for asset management in the DX era, it becomes a crucial research task to integrate the big data accumulated in a decentralized manner by process and structural type. The key challenges are to transform this data into information that enhances decision-making and to create insights that deepen road policies.

2. Activities in Research Period

RQ1-1: Develop a method to quantitatively evaluate the deterioration suppression effect of repairs using a deterioration prediction model that considers sample selection bias for damages that have been repaired.
RQ1-2: Develop a deterioration and recovery prediction method that can estimate 1) the amount of health recovery at the time of repair and 2) the heterogeneity (relative difference) in deterioration speed before and after repair by treating the health before and after repair as latent variables, specifically for road infrastructure that has experienced repairs.
RQ2: Develop a multivariate deterioration process model using continuous variables for expressway pavements to be used for prioritizing repairs and selecting repair methods.
RQ3: Consider the planning of long-life plans (individual facility plans) for bridges as part of the EBPM examination content. Develop a flow for determining repair priority based on statistical deterioration prediction results and fault tree analysis (visualization of risk paths from components to the entire bridge system and quantitative risk assessment).
RQ4: Develop a methodology to determine management measures by optimizing a long-term plan that shows repair policies over multiple years and a short-term plan that shows specific annual repair schedules, specifically for road pavements in a road network.

3. Study Results

RQ1-1: Developed a methodology using a Markov deterioration hazard model to quantitatively analyze the effect of simple repair measures (inspection-time measures) on suppressing deterioration and damage occurrence, considering sample selection bias. By expanding the concept of sample loss, we estimated missing deterioration processes and proposed a method to evaluate the impact of inspection-time measures on damage groups by defining the rate of change in damage numbers over five years.
RQ1-2: Developed a methodology to predict pavement structure deterioration and evaluate layered repair effects for expressway pavements with high-performance surfaces. By modeling the load-bearing capacity transition as a composite process of deterioration and recovery, we proposed an estimation method based on survey data and repair history, enabling quantitative evaluation of repair effects and deterioration prediction.

RQ2: Developed a methodology for planning preventive repair measures by applying a multivariate deterioration process model using continuous variables to pavement indicators (crack rate, rutting amount, IRI) measured by FWD and surface condition surveys. The model, considering heterogeneity, estimated expected lifespan and deterioration speed. Using an Archimedean copula, we grouped heterogeneity in pavement indicators, enabling evaluation of large-scale or preventive repair necessity.
RQ3: Developed a flow for determining repair priority in bridge facility plans for EBPM. Using a Poisson-Gamma model, we represented damages occurring within the target period for bridge components. A simulation model using a mixed Markov deterioration hazard model represented deterioration processes. Damage risks were systematized using fault tree analysis, allowing identification of priority bridge components for repairs.
RQ4: Developed a new methodology for optimizing long-term plans by splitting pavement system management into long-term and short-term plans and optimizing each. We sampled traffic regulation costs, user costs, and repair section numbers from the optimized short-term plan, estimated an approximate cost function, and optimized the long-term plan based on these results. This method considers the non-linearity of costs, enabling more realistic long-term plan optimization.

4. Papers for Presentation

1) Midori Ando, Koya Shikata, **Kiyoyuki Kaito**, Kotaro Sasai, Naruaki Tsukamoto, and Nariaki Yamashita: "Effectiveness of Inspection Measures in Suppressing the Occurrence of Repairable Damages," AI and Data Science Journal, Vol. 4, pp. 582-595, November 2023.
2) Yuto Nakazato and Daijiro Mizutani: "Optimization of Annual Repair and Regulation Plans by Day and Section in Road Networks: Bi-level Solution Method," 68th Civil Engineering Planning Research Presentation, Autumn Conference, November 2023.
3) Kotaro Sasai, Iori Yoshida, Manish Man Shakya, and **Kiyoyuki Kaito**: "Proposal of Pavement Maintenance Management Method Using Multivariate Deterioration Process Model with Continuous Variables," 78th Annual Academic Conference, Japan Society of Civil Engineers, VI-519, Hiroshima Institute of Technology, September 2023.
4) **Kiyoyuki Kaito**, Kiyoshi Kobayashi, Keizo Kamiya, and Yusei Nii: "Evaluation of Deflection Recovery Quantity by Layered Repair Considering Deterioration and Recovery Processes," Journal of the Japan Society of Civil Engineers, Vol. 79, No. 1, 22-00130, January 2023.
5) Yusei Nii, **Kiyoyuki Kaito**, Kiyoshi Kobayashi, and Keizo Kamiya: "Hidden Markov Deterioration Model for Quantitative Evaluation of Layered Repair Effects," 6th JAAM Research and Practice Presentation, Japan Asset Management Association, pp. 61-67, Online, November 2022.

5. Study Development and Future Issues

With the goal of practical application and social implementation of the research results, we will continue to improve model accuracy through the integration of different data sources and the introduction of new sensor technologies. We will also explore methods to more effectively integrate the accumulated big data. The research outcomes will be utilized in projects like the SIP 3rd Phase Task "Construction of a Smart Infrastructure Management System" (duration: 5 years from 2023), for which the principal investigator, Kaito, serves as the research and development manager of the sub-task.

6. Contribution to Road Policy Quality Improvement

This research and development aimed to address issues related to recent road policies, including the obligation of regular close visual inspections, the advancement of hardware technology, the promotion of DX, and the promotion of EBPM. Additionally, we have created a draft of the Statistical Deterioration Prediction Technology Manual, paving the way for the dissemination and standardization of infrastructure asset management technologies.

7. References, Websites, etc.

None