

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

No.	Title	Principal Researcher
No.2023 - 1	Technology Development of Digital Twin-based Management System for Winter Road Transportation	Hokkaido Univ. Associate Prof. Sho Takahashi

This project aims to reduce the burden and improve the efficiency of the movement of people and goods during the winter season. It focuses on developing a digital twin that utilizes a road API to exchange dynamic data between the physical and cyber worlds, thereby enabling the prediction of future road traffic conditions. Specifically, the project involves collecting real-time data on winter road conditions using edge computing with minimal data transmission, building an AI-based digital twin using this data, and exploring methods for its practical implementation in road traffic management.

1. Backgrounds and Objects

One of the basic policies of the 8th Hokkaido Comprehensive Development Plan is to realize the “maintenance and formation of a Hokkaido-style regional structure” consisting of three layers: “production areas,” “urban centers,” and “regional hub cities,” which collectively provide the “food” and “tourism” that are Hokkaido’s strengths. Amid a declining population, maintaining a road transportation network that sustains and improves the frequency of movement of people and goods is crucial. However, Hokkaido’s winters, compounded by increasingly extreme weather, frequently bring heavy snowfall, reduced visibility, snowdrifts, and icy road surfaces, causing road conditions to change rapidly and hindering the movement of people and goods both within and between cities. In fact, heavy snowfall in the Ishikari region of Hokkaido in February 2022 severed the road network in the Sapporo metropolitan area. Because public transportation service information was not provided in a centralized manner, large numbers of people were stranded at Sapporo Station and New Chitose Airport, and some were unable to return home. Furthermore, despite the record-breaking snow damage and the resulting paralysis of traffic throughout the city, the failure to effectively encourage changes in behavior among motorists exacerbated traffic congestion, significantly impacting citizens’ daily lives and the local economy.

Given this background, winter road traffic management—including accurate forecasting of weather and traffic conditions, rapid and appropriate traffic control and movement restrictions, and snow removal operations—is considered essential. Therefore, this study aims to construct a winter road traffic management system using a digital twin equipped with a road API in cyberspace, with the goal of realizing advanced mobility support in snowy and cold regions. This will enable the provision of safe and comfortable road traffic throughout the year.

The developed digital twin features a road API that exchanges dynamic data between the physical and cyber spaces and utilizes AI to predict anticipated future road traffic conditions, thereby contributing to traffic management. Since winter road traffic conditions are influenced by weather and change moment by moment, we process dynamic data such as traffic and weather data, send it to cyberspace via the Road API, and run simulations. This allows us to provide road administrators and road users with predictions of future road traffic conditions via the Road API.

2. Activities in Research Period

In this study, we have identified the following five themes as part of the technological development leading to a winter road traffic management system based on digital twins.

- [1] Development related to forecasting using a digital twin composed of winter road environment, traffic, and weather data
- [2] Development related to the construction of a winter road traffic management system based on digital twins
- [3] Development of technologies for simulations and advanced traffic utilizing traffic and meteorological data
- [4] Development of technologies to reduce the burden of human mobility in snowy and cold regions
- [5] Examination of methods for the societal implementation of a winter road traffic management system based on a digital twin equipped with a road API

3. Study Results

We developed a digital twin that serves as the foundation for a winter road traffic management system (**Fig. 1**). We established a system that integrates winter road environment, traffic, and weather data; provides simulation

capabilities; and features a web interface for disseminating insights derived from this data. Additionally, we established a framework for linking this system with local FM radio and other platforms.

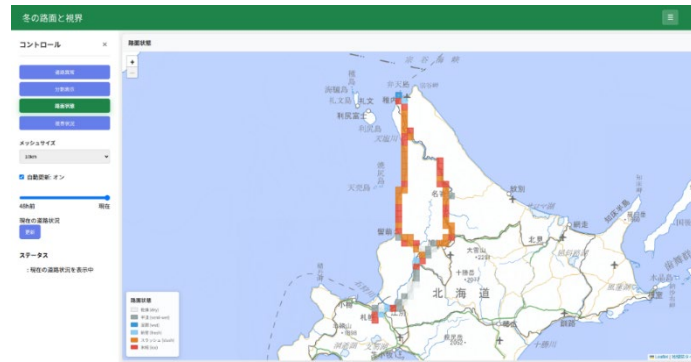


Fig. 1 An example screen of digital twin system.

4. Papers for Presentation

This research resulted in 24 peer-reviewed papers, 15 presentations at international conferences, and 30 presentations at academic conferences. The main published papers are as follows.

- [1] Masahiro Yagi, Sho Takahashi, Kazuhito Ohashi, Yasuhiro Nagata, Toru Hagiwara, “Predicting Visibility Conditions at the CCTV Installation Site Using Long Short-Term Memory,” Transportation Research Record, 2026. (Accepted for publication)
- [2] Chinami Fukui, Yuki Tan, Sho Takahashi, Toshio Yoshii, Toru Hagiwara, “A Study on the Provision Method of Visibility Information in Winter and Its Effects on Behavioral Intention,” JSCE Journal of AI and Data Science, May 2025.
- [3] Tran Vinh Ha, Mikiharu Arimura, “The Application of ETC2.0 Probe Data and Network Clustering in Investigating Urban Mobility Patterns During an Extreme Snow Event,” International Journal of Intelligent Transportation Systems Research, Feb. 2025.

5. Study Development and Future Issues

Throughout this research project, we conducted technological development and demonstration of road information provision utilizing digital twins, with the aim of reducing the burden of human mobility during the winter season. Through these efforts, we confirmed the effectiveness of providing information that encourages behavioral changes, such as selecting safer routes and refraining from unnecessary travel, and compiled insights, a roadmap, and an implementation manual for deployment in other regions. These findings have resulted in a framework for information provision that can be utilized in road administration and are expected to contribute to the next generation of road administration by improving the quality of road policy. From the perspective of methodology development, we have successfully implemented a digital twin system, and our pilot information provision efforts have received positive feedback from users. However, it is necessary to continue research and development in the future, focusing on improvements to the user interface and the provision of highly accurate information through data fusion.

6. Contribution to Road Policy Quality Improvement

In order to fully incorporate the findings of this study into future road administration practices, collaboration with government agencies will be necessary—including the establishment and operation of a “(tentative name) Information Center” that provides information useful for road administration, as well as the provision of information tailored to the needs of road users and other stakeholders. If this can be achieved, it will significantly contribute to improving the quality of road policy. Accordingly, this study has compiled insights, manuals, and implementation strategies for applying these findings to road administration.

7. References, Websites, etc.

Laboratory of Advanced Mobility and Transportation Engineering, Hokkaido University

<https://www.eng.hokudai.ac.jp/labo/kyoku/>

Leaflet of Digital Twin System with FM Moeru

https://www.eng.hokudai.ac.jp/labo/kyoku/document/moeru_digitalTwin/digitaltwin.pdf