学　位　論　文　内　容　の　要　旨

DISSERTATION ABSTRACT

博士の専攻分野の名称　　博士（工学）　　氏名　洪 性敏

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Development of A Travel Speed Estimation Model for Effective Snow Removal Operations on Urban Arterial Roads

(街路における効率的な除雪作業のための旅行速度推定モデルに関する研究)

Traffic congestion in winter is affected not only by travel speed, traffic volume and density, but also by external factors such as weather conditions, road works, road surface conditions and snow removal operations. To explain traffic conditions, transportation engineers need to identify and analyze these factors. Previous researchers have addressed the relationship between traffic performance and non-traffic factors, including weather conditions, using data collected by various sensors. And many researchers have developed travel time and traffic condition prediction models. However, they have not considered the effects of snow removal operations in microscopic approaches on travel time or traffic conditions for forecasting winter traffic congestion, which means that they did not evaluate traffic performance according to snow removal for each road. Therefore, the purpose of the present study is to develop the methodology for travel speed prediction model that consider weather conditions and snow removal operation factors, toward estimating cost-effectiveness of snow removal operations in Sapporo. Cyber-physical system (CPS) is a smart cycle system that analyzes and collects real-world data, and then the real-world can be given feedback from the analysis results. CPSs allow us to collect valuable data, such as traffic data, weather data and snow removal operation factors from advanced sensors. Physical-world data are now easily convertible into computerized data through CPSs.

The location of the present study was a 4.8-km section of Nishi-5-chome Tarukawa Dori, a major arterial in Sapporo, Japan. The duration for analysis was on weekdays for the winter season of 2013-2014 (December, 2013 to March, 2014). The variables of traffic conditions, weather conditions, and snow removal operation factors were considered for the analysis in the present study. Five steps were performed to develop the travel speed prediction model for the effective snow removal operations. The first step was to establish a dataset for analysis by combining traffic conditions, weather conditions and snow removal operation factors. The second step was to develop multiple linear regression (MLR) models and panel data models with all the variables. The third step was to investigate the autocorrelation of the residuals between the actual and estimated values of the MLR models and the panel data models, in order to apply an autoregressive integrated moving average (ARIMA) model to the residuals. If the residuals were autocorrelated with among the others, they would be predicted by ARIMA model. This kind of model, which is combined both a regression model and an ARIMA model, is called a regression with ARIMA (RegARIMA) model. The fourth step was to verify the developed RegARIMA models under different weather conditions: snow conditions and non-snow conditions.

The fifth step was to estimate the cost-effectiveness of snow removal operations based on the travel time saving benefits.

According to the model verification, the developed RegARIMA model was more suitable for forecasting travel speed than the univariate ARIMA model, which is a prediction model using only the past observations, under snow weather conditions. The developed RegARIMA models showed that temperature had a U-shaped relationship with travel speed and snow depth had a negative correlation with travel speed. Snow removal for road widening had a positive correlation with travel speed. In contrast, fresh snow removal operations affected traffic in two opposite ways. Firstly, these operations can keep the roads in good condition by the removal of snow from the carriageway. Secondly, the effective road width is narrowed when the snow is pushed to the shoulders. In addition, the vehicle turning rate was negatively correlated and the intersection size had a positive relationship with travel speed. Vehicles going straight were affected by the vehicles turning left and right at intersection especially on the winter road which were narrowed by fresh snow removal operations. On the other hand, the negative effects of the turning rate would be decreased if the intersection size were big enough space to wait for an opportunity to turn right and left at intersections. From the estimation for the cost-effectiveness of snow removal operations, around 1,200 JPY per vehicle for the widening snow removal operations and 1,400 JPY per vehicle for the fresh snow removal operations could be found as the travel time saving benefits during the week from February 13 to February 20, 2014.

The results suggest a methodology for predicting the travel speed, considering weather conditions and snow removal operations in an urban area. This methodology can be used when forecasting traffic congestion in winter in an urban area, and it can be used for developing winter road maintenance strategies in an urban area. For example, the locations and times of traffic congestion could be predicted by the proposed methodology. Then, snow removal equipment could be deployed more economically in advance to the proper locations. The evaluation of snow removal operations also can be calculated by estimating travel speed or travel time. To develop the present study further, the road networks of the city should be considered, in which case the effectiveness of snow removal in reducing traffic congestion would be clearer.