Reinforcement Learning (RL)-based Real-time Variable Speed Limit (VSL) Optimization to Improve Safety on Urban Expressway

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(1) Introduction: This study proposes a proactive road safety management system integrating a real-time crash prediction model (RTCPM) with an intelligent agent capable of mitigating crash risks instantaneously. First, a micro-simulation model was calibrated to reproduce the traffic conditions in Route 4 (Shinjuku) of Tokyo Metropolitan Expressway. Then a Bayesian Network (BN)-based RTCPM and an RL-based VSL control agent were integrated to mitigate the real-time crash risks.

(2) Method: In this study, traffic data and crash data of route 4 Shinjuku of Tokyo metropolitan expressway is employed to create a real-time crash prediciton model (RTCPM). Figure 1 the schematic diagram of the Bayesian Nework-based RTCPM showing the information parameters and the data collection method for crash analysis. Microscopic simulaiton with VISSIM was conducted to visualize the change in traffic condition. In the RTCPM, traffic flow measurements were used as the informaiton variables for estimating the crash likelihood usng the Bayesian Network. This crash likelihood values were then utilized to create reinforcement learning-based variable speed limit control strategies as intervention to avoid the impending crashes. Five scenarios were generated using two different RL methods namely Q-learning (QL) and deep Q-netwrok (DQN) and for differnet lengths of the study segments to apply VSL.

(3) Result: The five scenarios of QL and DQN-based VSL application and the resulting improvement and deterioration of the number of crashes were compared. Figure 2 shows one of the scenarios where the results of applying DQN-based VSL strategies at nine segments in the study area are diagnosed. A crash risk threshold of 10 was selected as a criterion to see if the number of crashes is reduced or increased after applying the VSL control. From the figure, it can be observed that after applying DQN-based VSL control at the study segment, the number of crashes (with risk ≥10) are reduced in the targeted section. Hence, this can assist drivers to control their speed before they encounter the crash prone traffic condition. The other four scenarios are also analyzed with the same threshold of crash risk ≥10 to compare the results and investigate the appropriate length of road segment to apply VSL.

(4) Data:

- Traffic flow data, crash data (March ~ August 2014), Tokyo Metropolitan Expressway Company Ltd.

(5) Acknowledgments: This study was supported by JSPS KAKENHI Grant Number 25420535.

(6) Reference:

Abdel-Aty, M., and Wang, L. (2017). Implementation of variable speed limits to improve safety of congested expressway weaving segments in microsimulation. *Transportation Research Procedia* 27, 577-584.

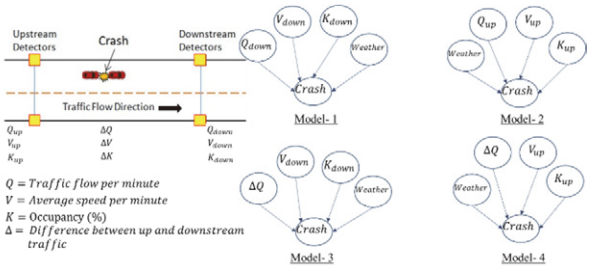

Figure1: Structure of RTCPMs with BN

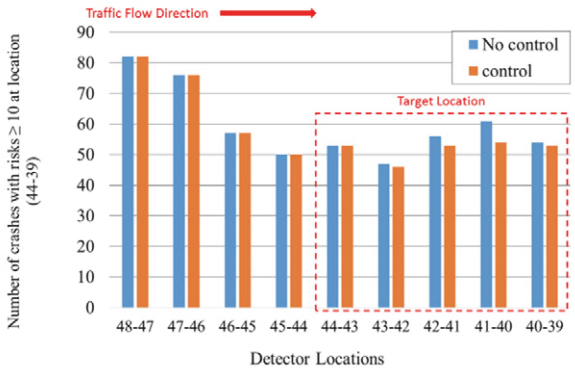

Figure2: Comparison of number of events with risk ≥10 with and without VSL Control (DQN)