Machine Learning Models for Predicting Capacity Reduction Rate Resulting from Queue Spillback due to Ramp Metering

Atika Jabin, Hector Mata and Dr. Mohammed Hadi
Department of Civil and Environmental Engineering, Florida International University
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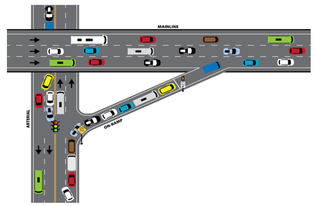
Introduction

Restriction of the vehicles from entering the freeway results in spillback to the feeding intersecting arterials. A strategy that predicts the queue spillback before it occurs, can be effective in reducing the impact of the ramp queues. If the spillback can be predicted before it occurs, it will be possible to activate a strategy to reduce the probability of queue spillback.



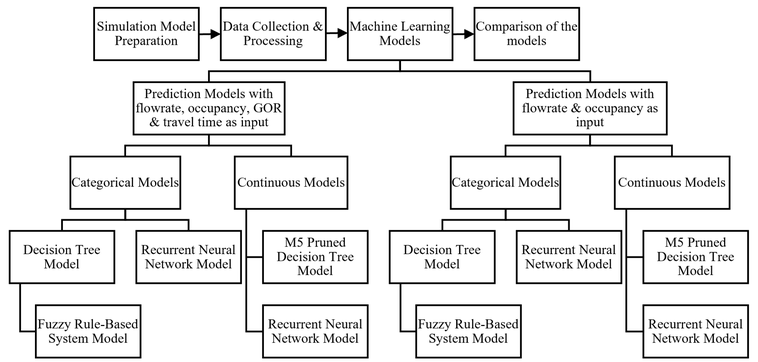
Research Objective

The objective of this project is to develop a machine learning based approach to predict the drop in capacity at the upstream intersection of the intersecting arterial caused by the queue spillback from the on-ramp due to ramp metering, before the queue spillback occurs.

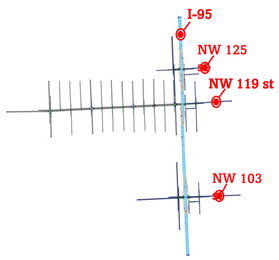
Study Network

- I-95 southbound segment,
- NW 119th St. in the vicinity of I-95, &
- On-ramp to the I-95 southbound from NW 119th Street.

Methodology



Simulation Modeling



- A VISSIM model was utilized for the study network.
- The model was developed and calibrated based on field data.
- The modeled segment included six signalized intersections of NW 119th St.

Modeled Variables

Variable	Type	Variable	Type
Eastbound Green Occupancy Ratio (GOR)	Input	Ramp Queue detector Flow Rate	Input
Westbound Green Occupancy Ratio (GOR)	Input	Ramp Queue Detector Occupancy	Input
Eastbound Flow rate	Input	Passage Detector Flow rate	Input
Eastbound Right lane Flow rate	Input	Passage Detector Occupancy	Input
Eastbound Travel time up to one upstream intersection	Input	Capacity Reduction Rate	Output
Eastbound Travel time up to two upstream intersection	Input	Category of Capacity Reduction Rate	Output
Westbound Left-lane Flow rate	Input		

Model Evaluation

Comparison of the Performance of the Categorical Models

		Weighted Average			Accuracy
		Precision	Recall	F1-score	
Prediction Models with all variables as inputs	DT	0.93	0.89	0.90	0.89
	FRBS	0.91	0.89	0.90	0.89
	RNN	0.98	0.97	0.97	0.97
Prediction Models with excluding GOR and travel time from input	DT	0.92	0.86	0.88	0.86
	FRBS	0.94	0.93	0.93	0.93
	RNN	0.98	0.97	0.97	0.97

Comparison of the Performance of the Continuous Models

		RMSE	MAE
Prediction models with all variables as inputs	M5P Decision Tree	0.024	0.012
	RNN	0.024	0.008
Prediction Models with excluding GOR and travel Time from Input	M5P Decision Tree	0.082	0.032
	RNN	0.028	0.009

Comparison of Categorical RNN Model and Continuous RNN model

		Mean Absolute Percentage Error	Category Prediction Accuracy
Prediction Models with all variables as inputs	Continuous RNN Model Outputs	7.4 %	96.8 %
	Median of Categorical RNN Model Outputs	24.7 %	99.4 %
Prediction Models with excluding GOR and travel times from inputs	Continuous RNN Model Outputs	8.6 %	95.5 %
	Median of Categorical RNN Model Outputs	25.0 %	98.1 %

Conclusion

- The models developed to predict the reduction in capacity as a continuous variable provided better prediction of the capacity reduction compared to the categorical models.
- The LSTM-based RNN models produced better results than the other models tested in this study.
- Excluding GOR and travel time variables from the input did not change the performance of the RNN models.