A Smart Application for Predicting Network-wide Congestion Hot Spots under Adverse Weather Conditions

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Agenda

1 **Introduction**

2 **Objective**

3 **Methodology**

4 **Application**

5 **Conclusions**

INTRODUCTION

- Most of the studies are concerned about monitoring traffic conditions under adverse weather conditions
- Previous studies predict traffic speed under normal conditions using deep learning using:
  - Deep Neural Networks
  - Recursive Neural Networks
- There are some research papers that use deterministic models to predict traffic speed under weather conditions, but they lack the ability to consider various weather variables

Why to predict traffic congestion due to adverse weather conditions?

- Predict congestion hot spots due to adverse weather conditions for congestion mitigation plans

- Allocate larger resources to higher congestion hot spot segments at certain times depending on the output of the application

BACKGROUND

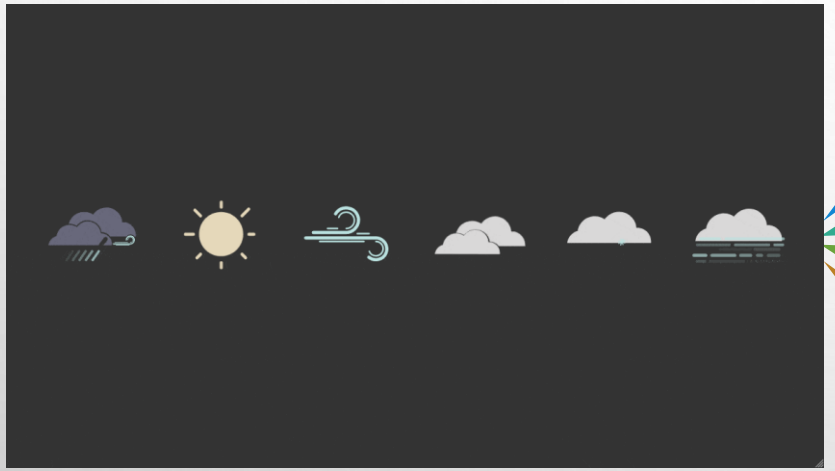
- Adverse weather conditions that affect traffic speed can be categorized into:
  - Rain Conditions
  - Fog Conditions
  - Snow Conditions

Weather Conditions	Freeway Average Speed Reduction*
Light Rain/Snow	3% - 13%
Heavy Rain	3% - 16%
Heavy Snow	5% - 40%
Fog	10% - 12%

* FHWA. (2018, September 17). How Do Weather Events Impact Roads? Retrieved October 8, 2019, from https://ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

BACKGROUND (CONT.)

Weather Conditions



Fog Conditions
Increases vehicles headways and decreases traffic speed.

Rain Conditions
Can cause Capacity reduction (10% - 30%) depending on the rain intensity.

Snow Conditions
Snow accumulation impedes the traffic reducing the traffic speed.

Wind Conditions
Wind conditions can reduce drivers' visibility when combined with rain or snow conditions.

OBJECTIVE

- The objective of this study is to propose a smart application that predicts freeway congestion hot spots due to adverse weather conditions.
- This study provides a system that covers the **New Jersey freeway network** and can capture the effect of three different weather conditions:
  - **Rain** Conditions
  - **Snow** Conditions
  - **Fog** Conditions

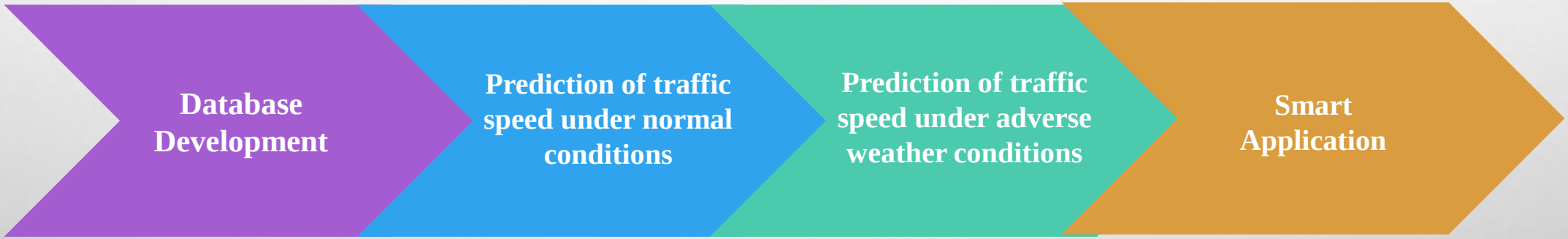
SYSTEM FRAMEWORK

Predictions of traffic speed under normal conditions

Based on the traffic speed from previous time stamps

Smart Application

Based on real-time feed from the databases. The application show a network-wide prediction of hot spot congestions



Database Development

Big data analysis is conducted on traffic speed and weather conditions data

Predictions of traffic speed under adverse weather conditions

Based on the output from traffic speed prediction under normal conditions and weather data

DATABASE DEVELOPMENT

Probe Vehicle Data

Captures Traffic Speed

New Jersey Congestion Management Systems

Estimates Traffic Volume

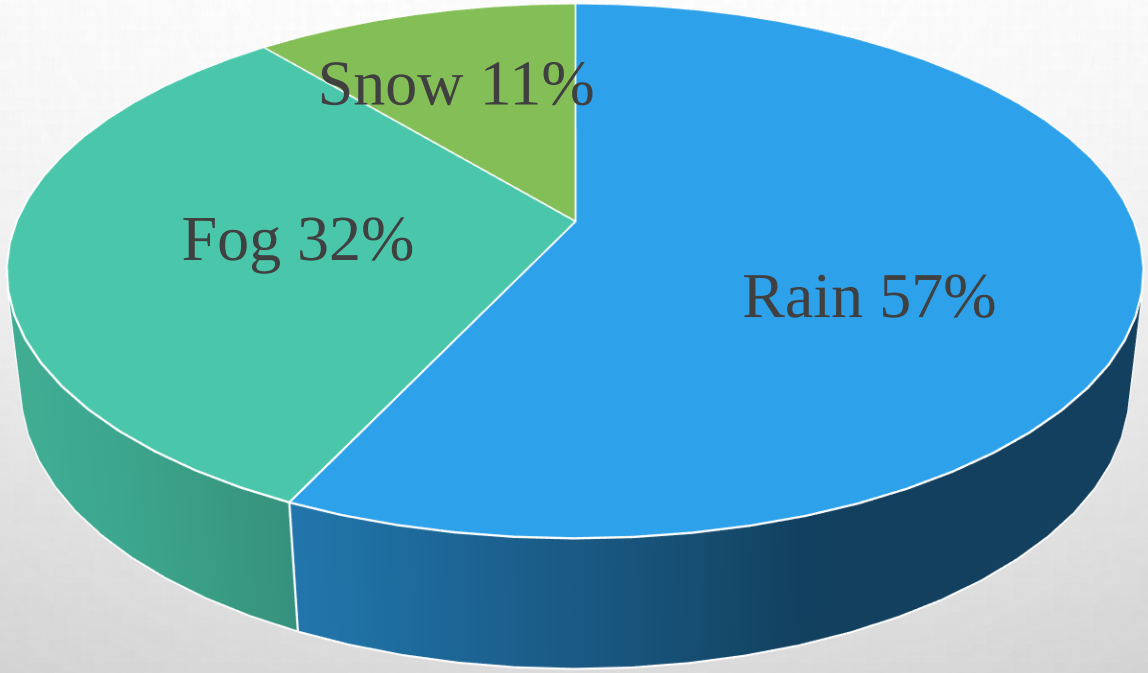
New Jersey Straight Line Diagram

Relates All the Databases in terms of Geographical Locations

NOAA

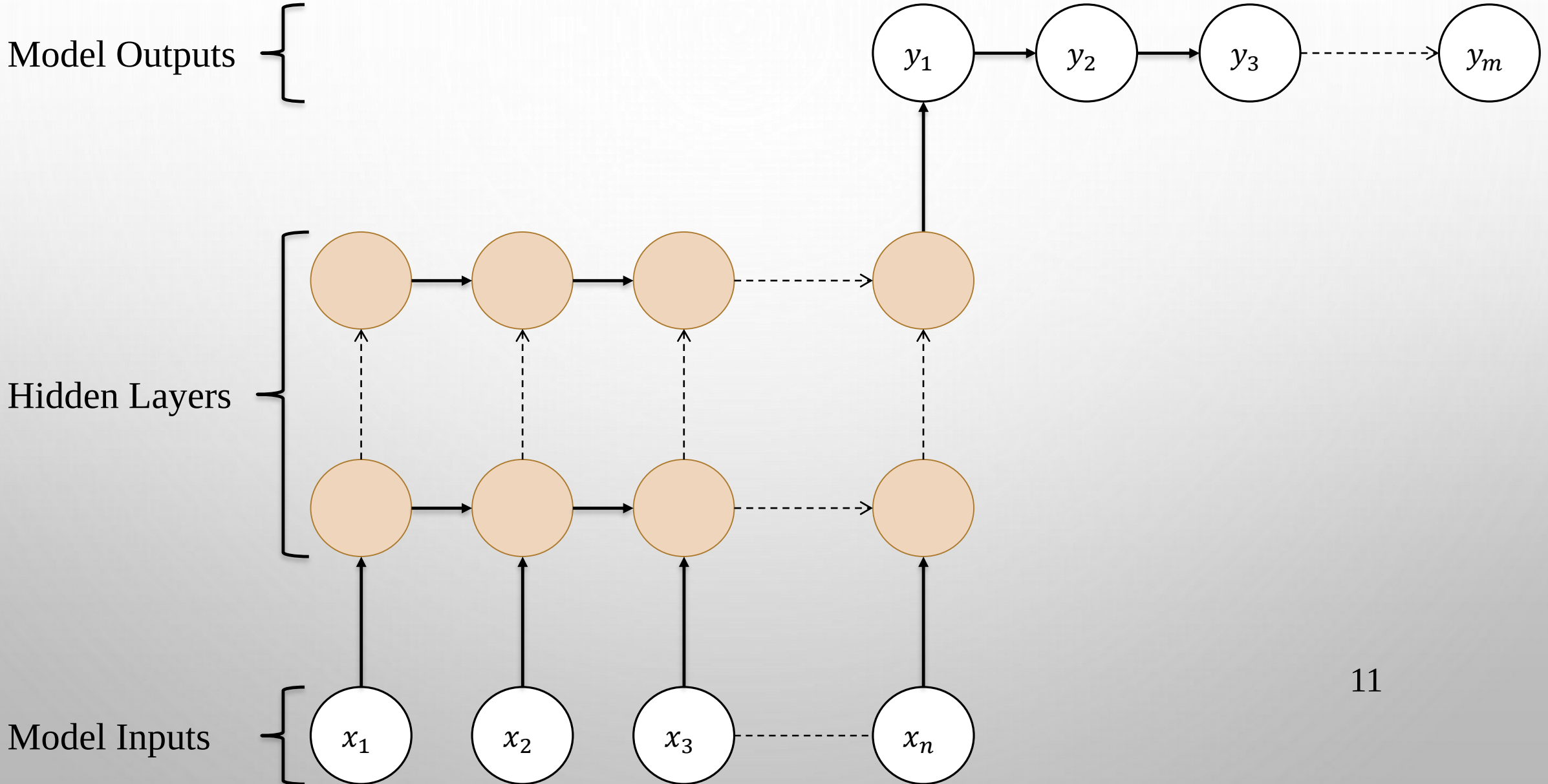
Provides Weather Information

DISTRIBUTION OF THE ADVERSE WEATHER CONDITIONS IN TERMS OF (MILES-HOURS)



*The data is based on weather conditions from 2014 until 2019 in all New Jersey Freeway Network

RECURRENT NEURAL NETWORKS



PREDICTING TRAFFIC SPEED UNDER NORMAL CONDITIONS

Model Inputs

Traffic Speed of previous 2 days

Recurrent Deep Learning model through two hidden layers

Model Outputs

Prediction of Traffic Speed under Normal Conditions for the next 24 hours

PREDICTING TRAFFIC SPEED UNDER ADVERSE WEATHER CONDITIONS

The Model uses recurrent neural networks through four hidden layers to account for queuing congestions over time

Visibility

Volume/Capacity

Rain/Snow Intensity

Weather Condition Type

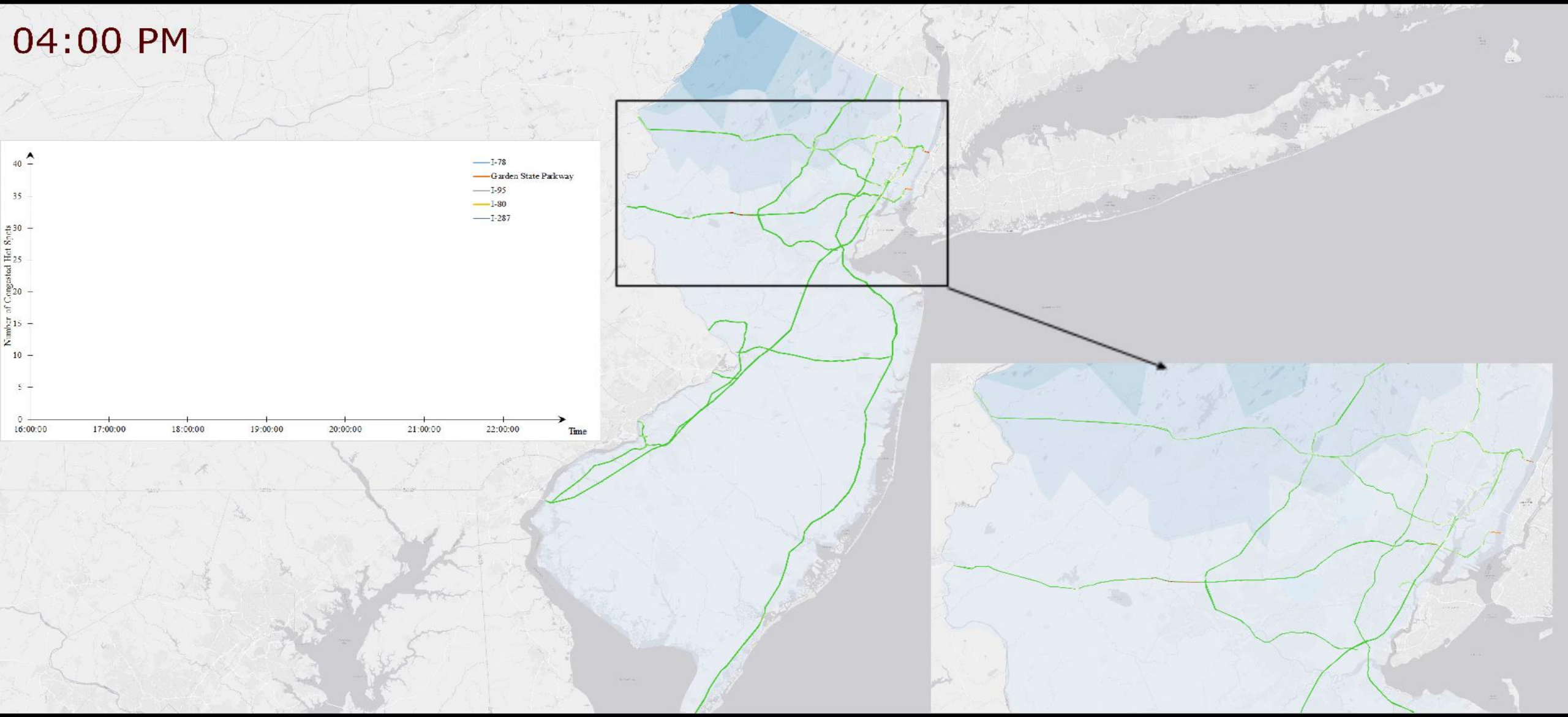
Wind Speed

Wind Direction

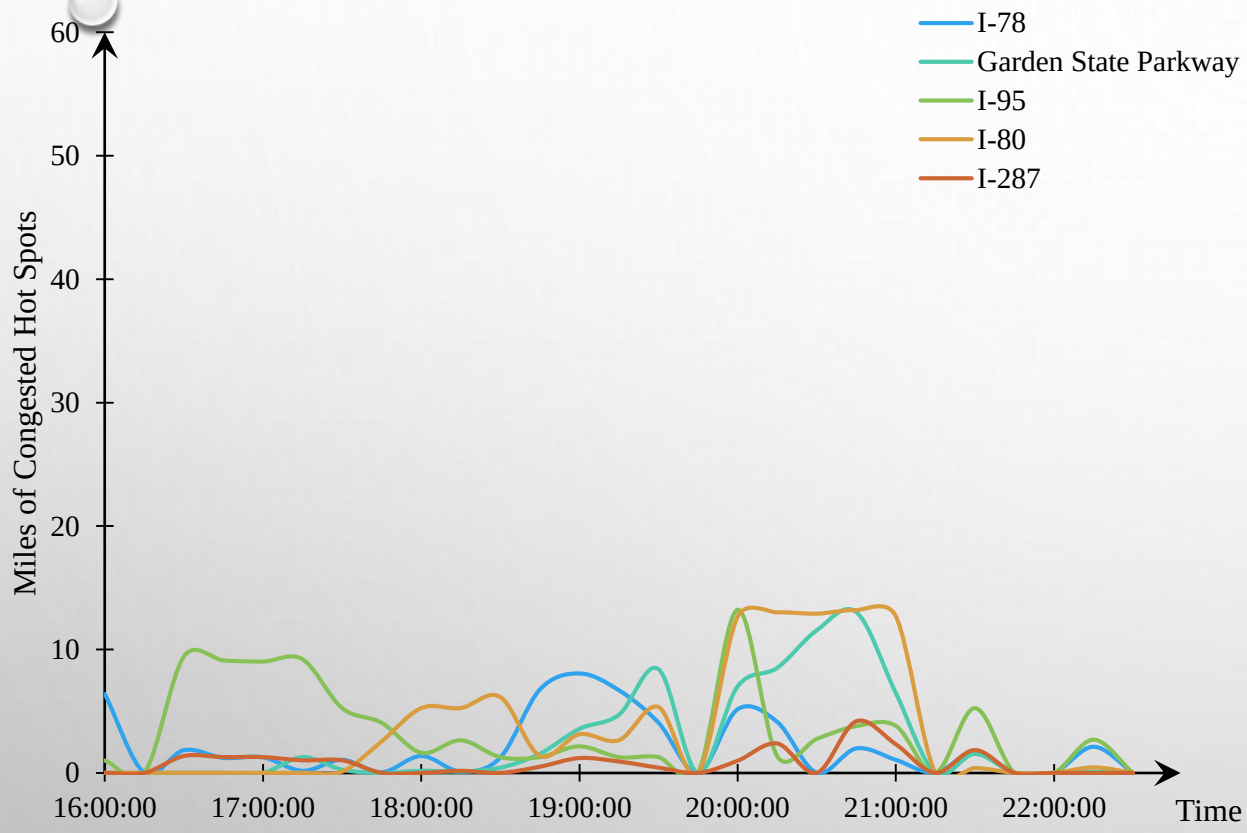
Predicted Traffic Speed under Normal Conditions

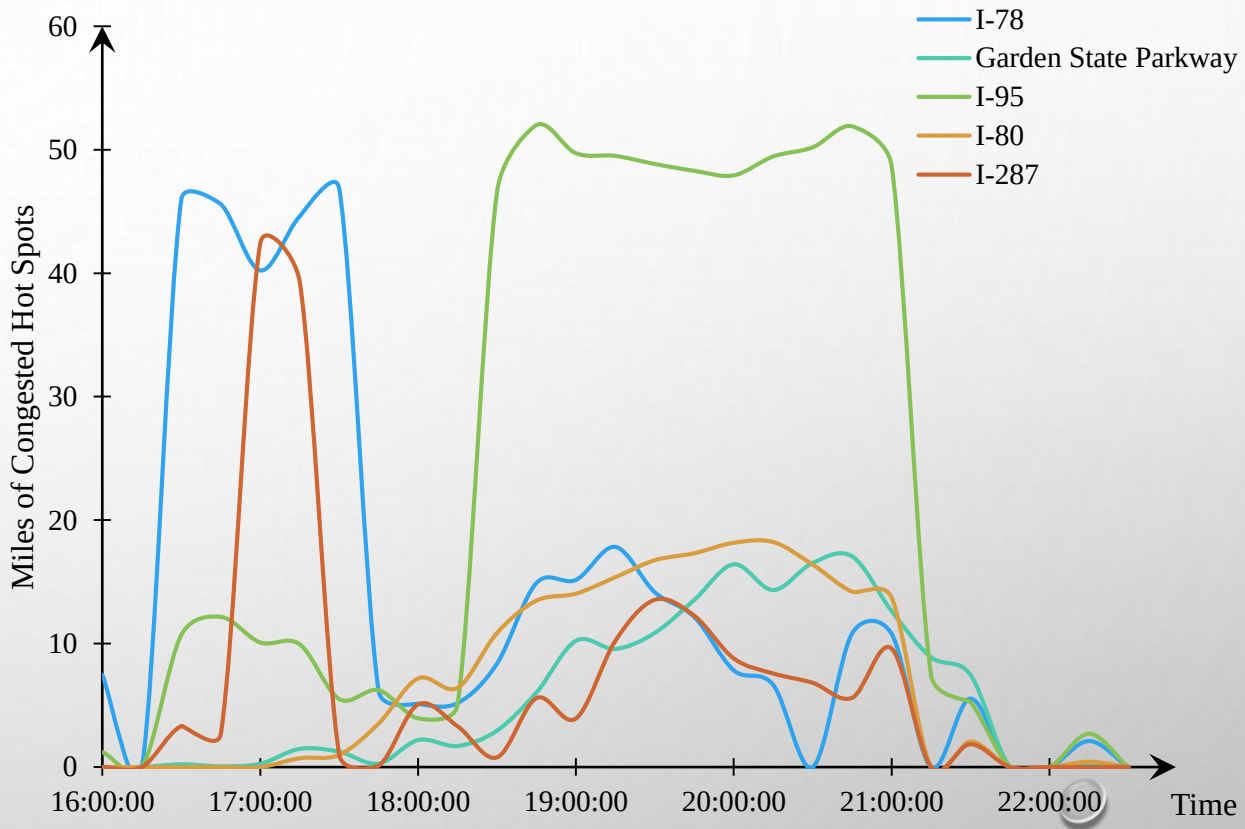
APPLICATION

- Heavy Rain occurred in July 22nd , 2019
- The rain starts around 4:00 PM at some New Jersey areas and extends until 10:00 PM
- The analysis is conducted July 22nd , 2019 at 1:00 PM (3 hours prior to the prediction starting time)
- Interstate-78 (Eastbound direction) is selected for further illustrations
- Hot spot congestion is considered when traffic speed is below 25 mph

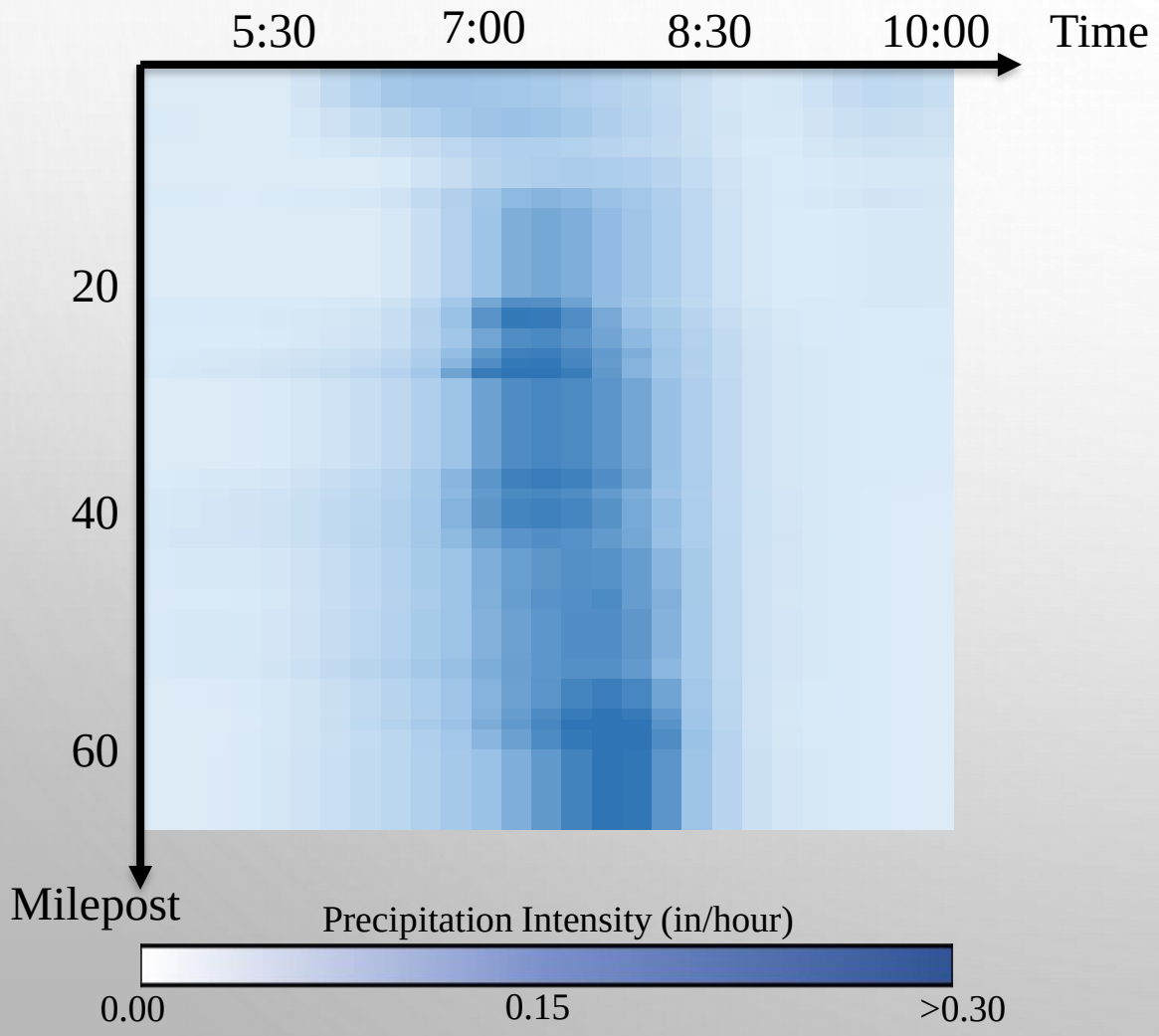


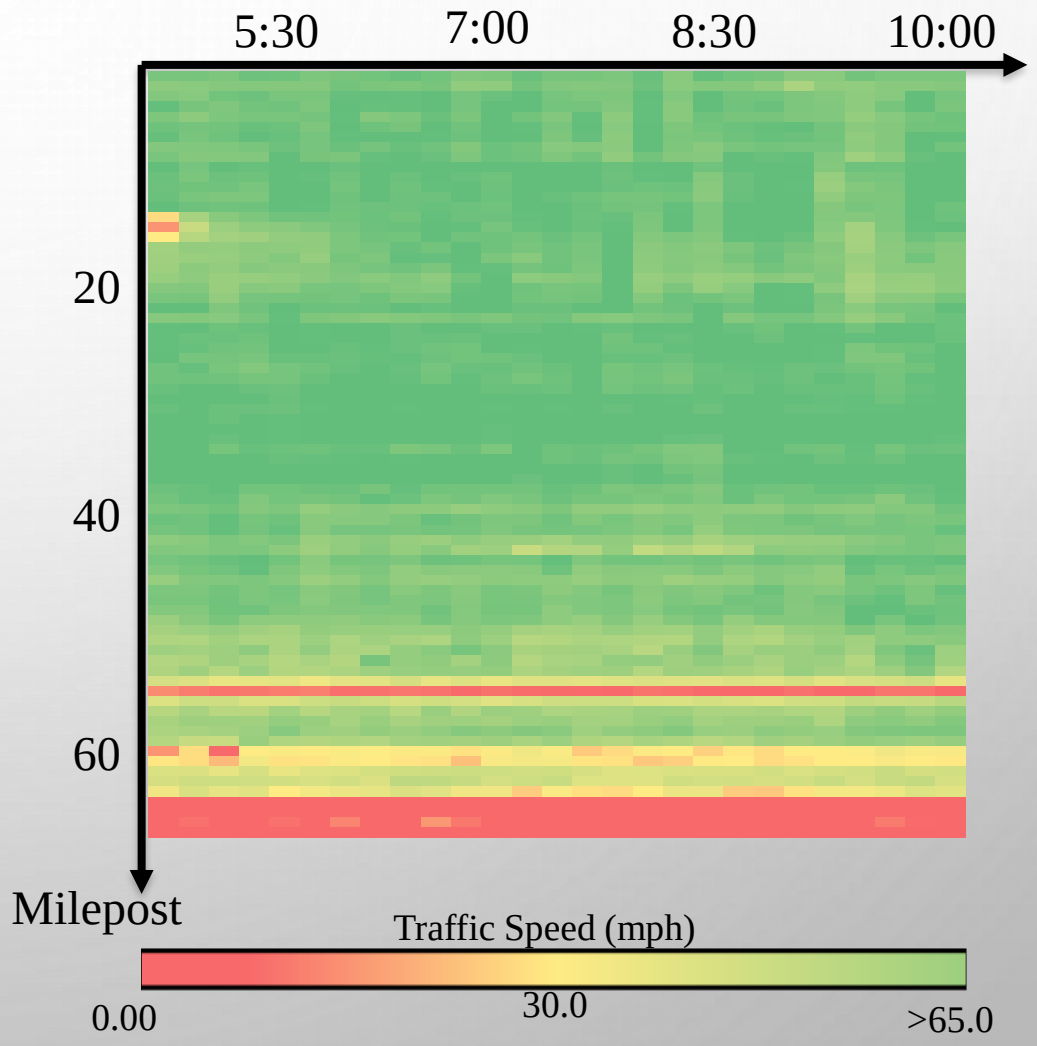
NORMAL CONDITIONS VS. PREDICTED CONDITIONS



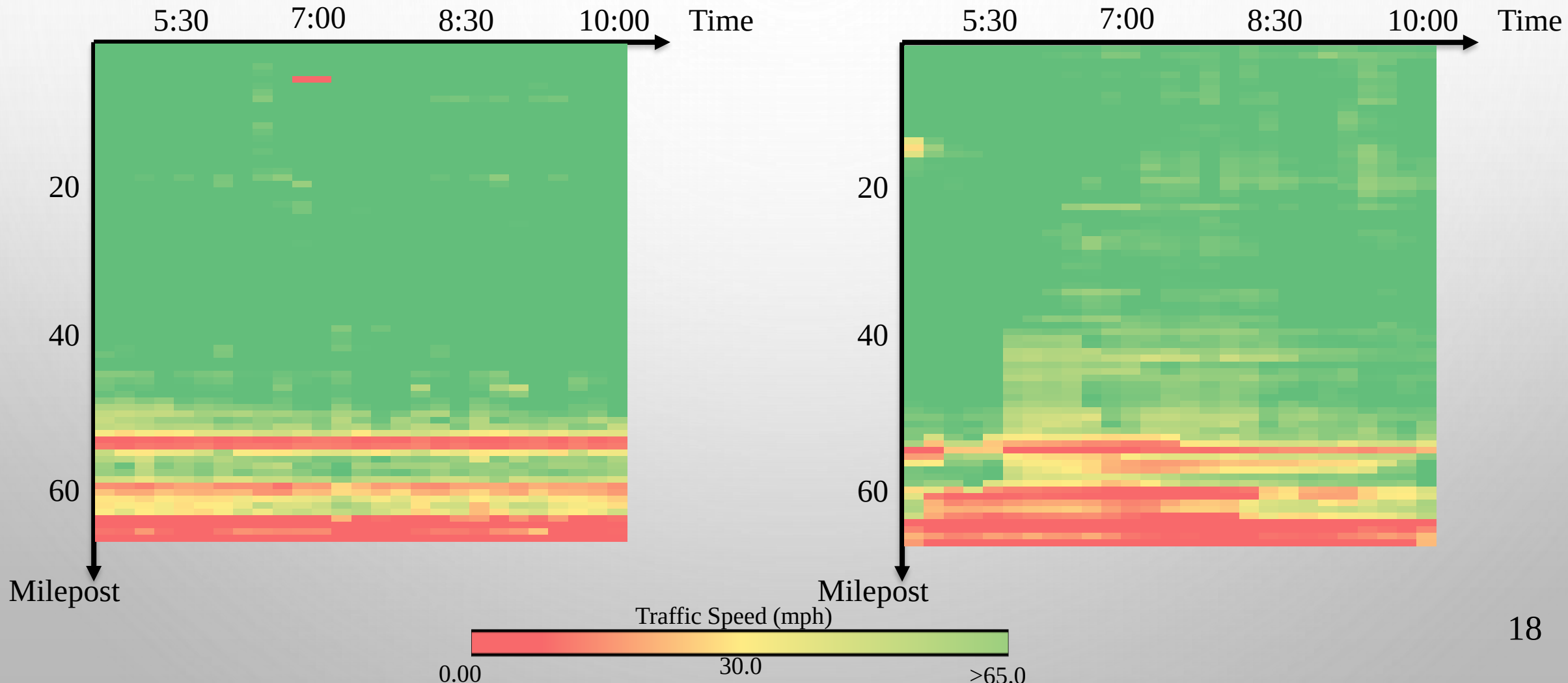


RAIN INTENSITY AND PREDICTED NORMAL CONDITIONS (I-78 EASTBOUND)

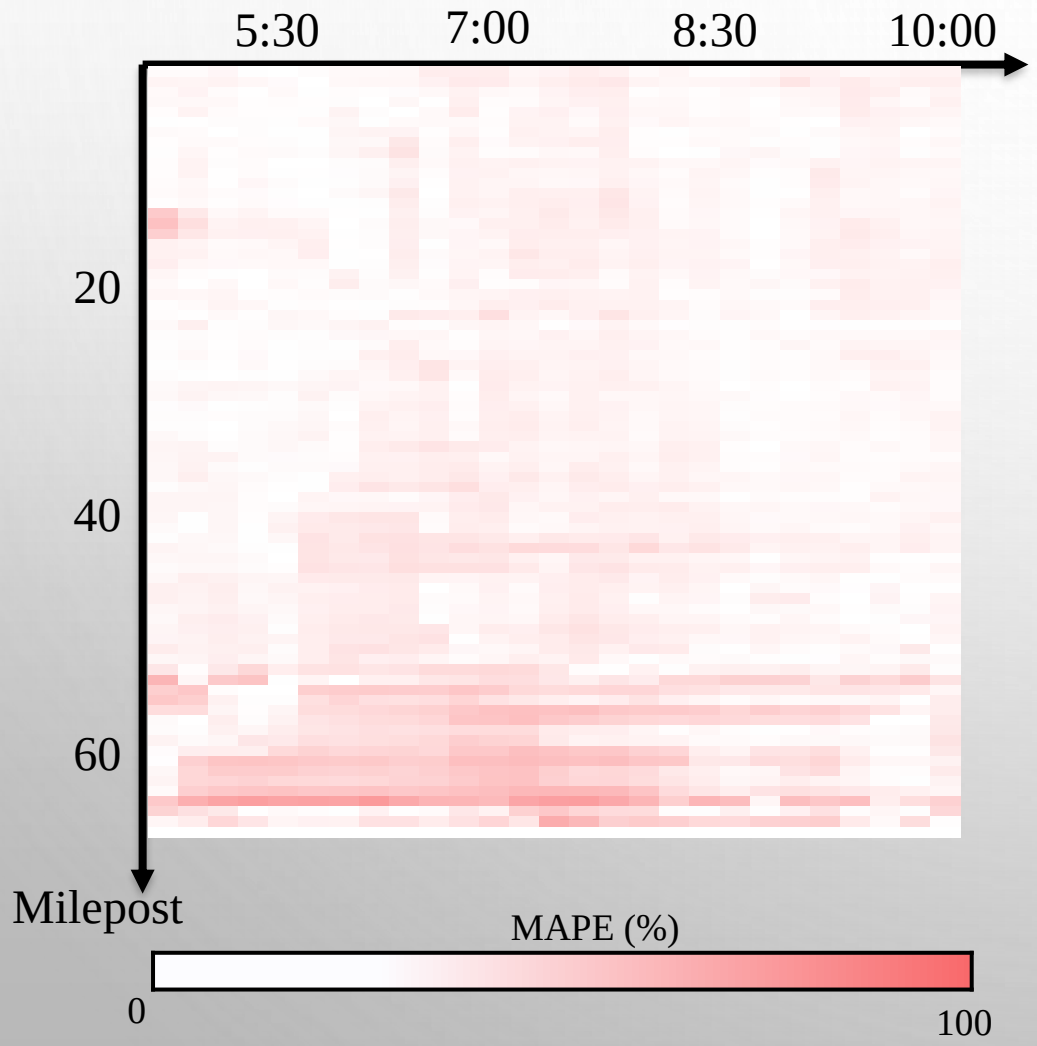


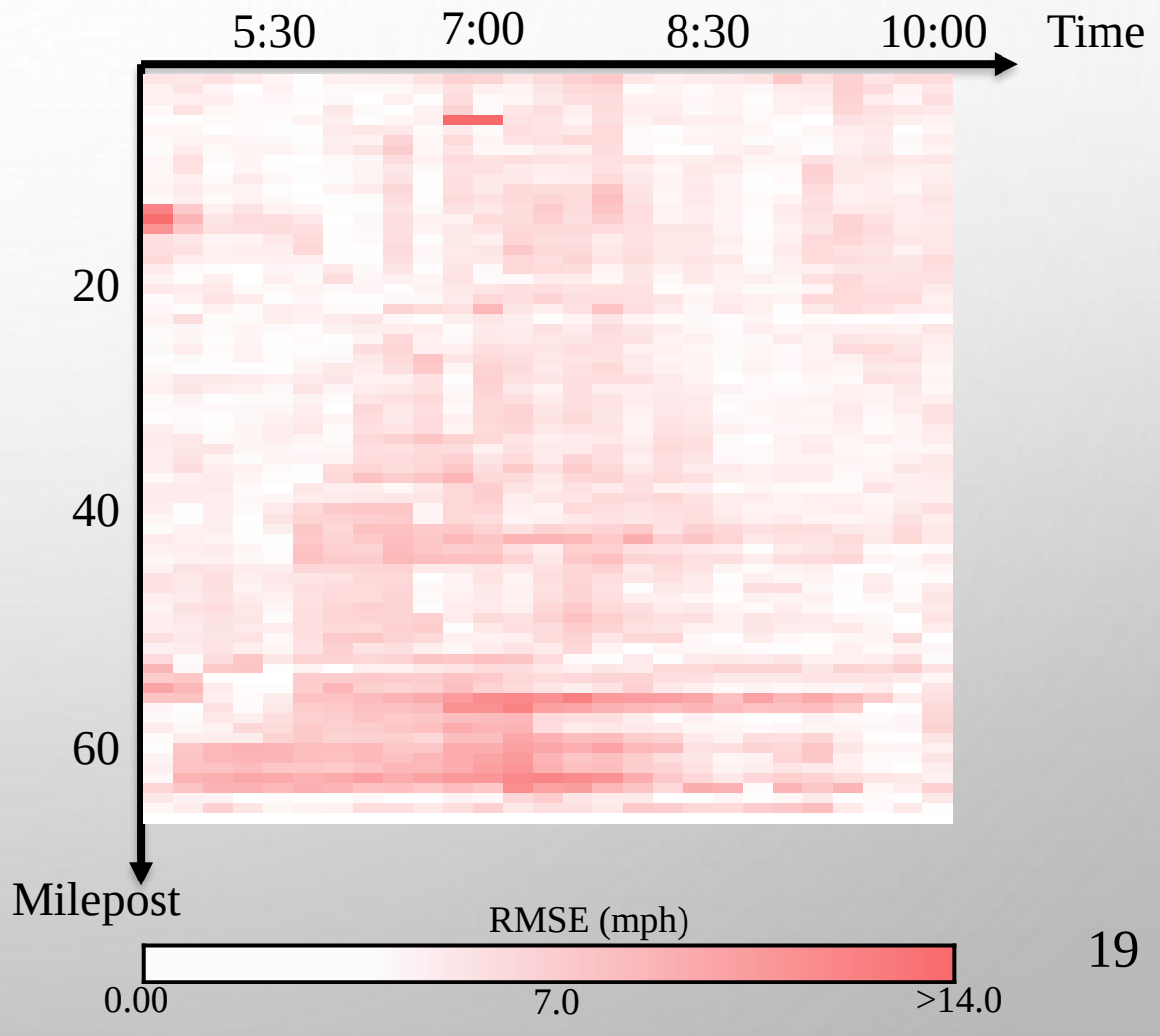


ACTUAL TRAFFIC SPEED VS. PREDICTED TRAFFIC SPEED (I-78 EASTBOUND)



MAPE VS. RMSE (I-78 EASTBOUND)

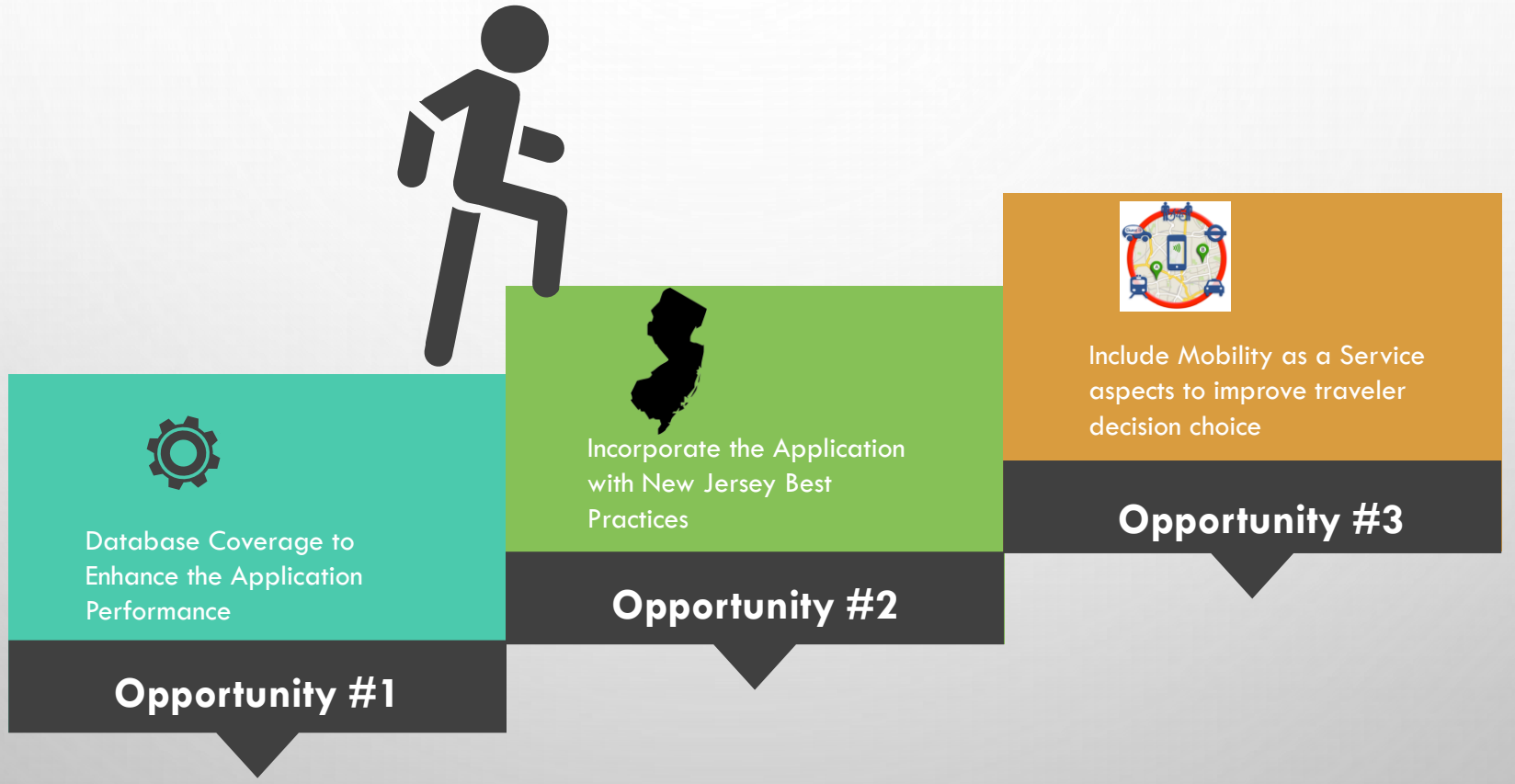




CONCLUSIONS

- This model provides a smart application to predict hot spot congestion on a network level due to adverse weather conditions
- Transportation agencies can use this application for congestion mitigation plans when adverse weather conditions are forecasted.
- The application can be used to optimize the resources when assigned to a network-wide locations depending on the predicted level of congestion.

RESEARCH OPPORTUNITIES



Thank You

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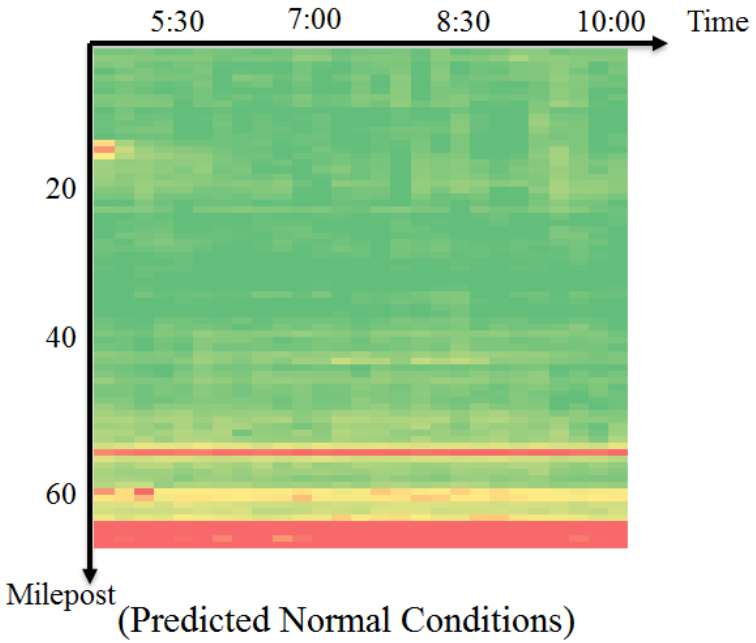
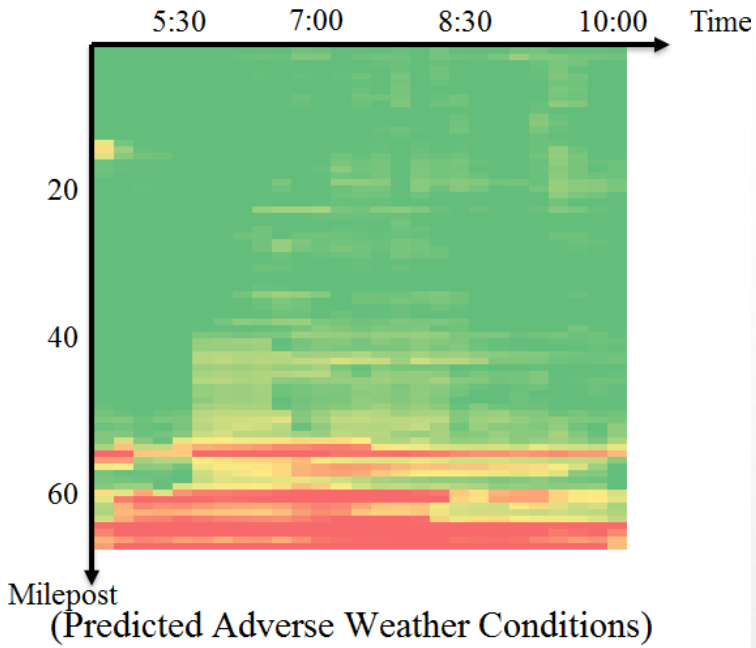
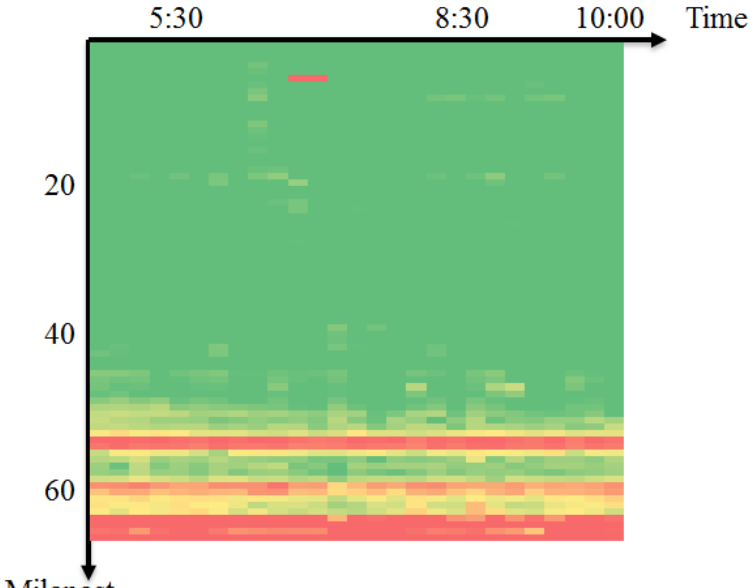


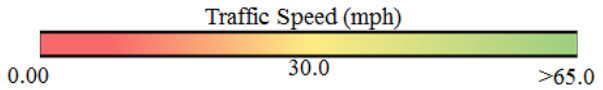
(Predicted Normal Conditions)

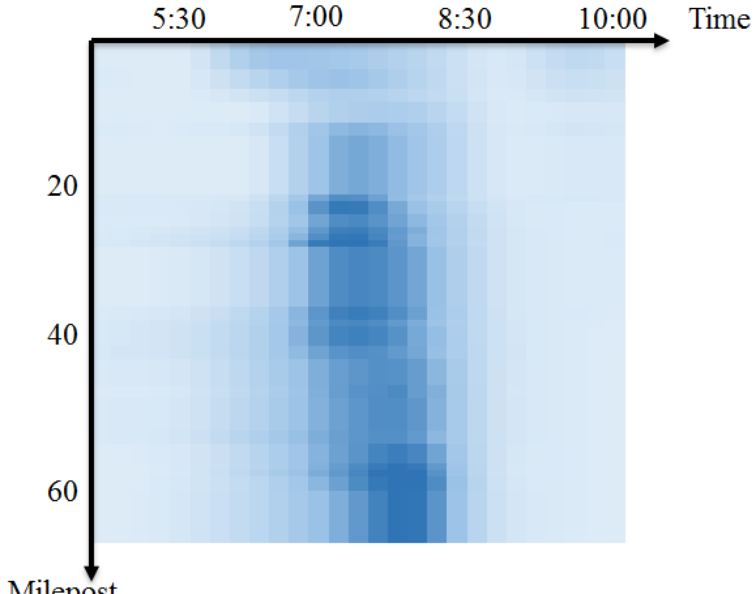


(Predicted Adverse Weather Conditions)



(Actual Traffic Speed)





(Rain Intensity)