

## Master's Thesis of Muhammad Mujtaba

### Mentoring:

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### 1. Problem & Motivation

- Freeway congestion is a major challenge in modern transport systems.
- Bottlenecks occur at ramp–mainline merge areas.
- Ramp metering is a commonly presented solution that regulates on-ramp inflow to control congestion on freeways.
- Conventional ramp control methods rely on predefined traffic models and fixed parameters.
- Limited adaptability under changing traffic conditions.

### 2. Proposed Approach

- Data-driven ramp metering using Model-Free Adaptive Control (MFAC) approach.
- Uses input–output traffic data to achieve adaptive control action. (no explicit model required)
- Eliminates need for model calibration and fixed predefined parameters
- Adaptive to nonlinear and uncertain traffic conditions

### 3. Methodology

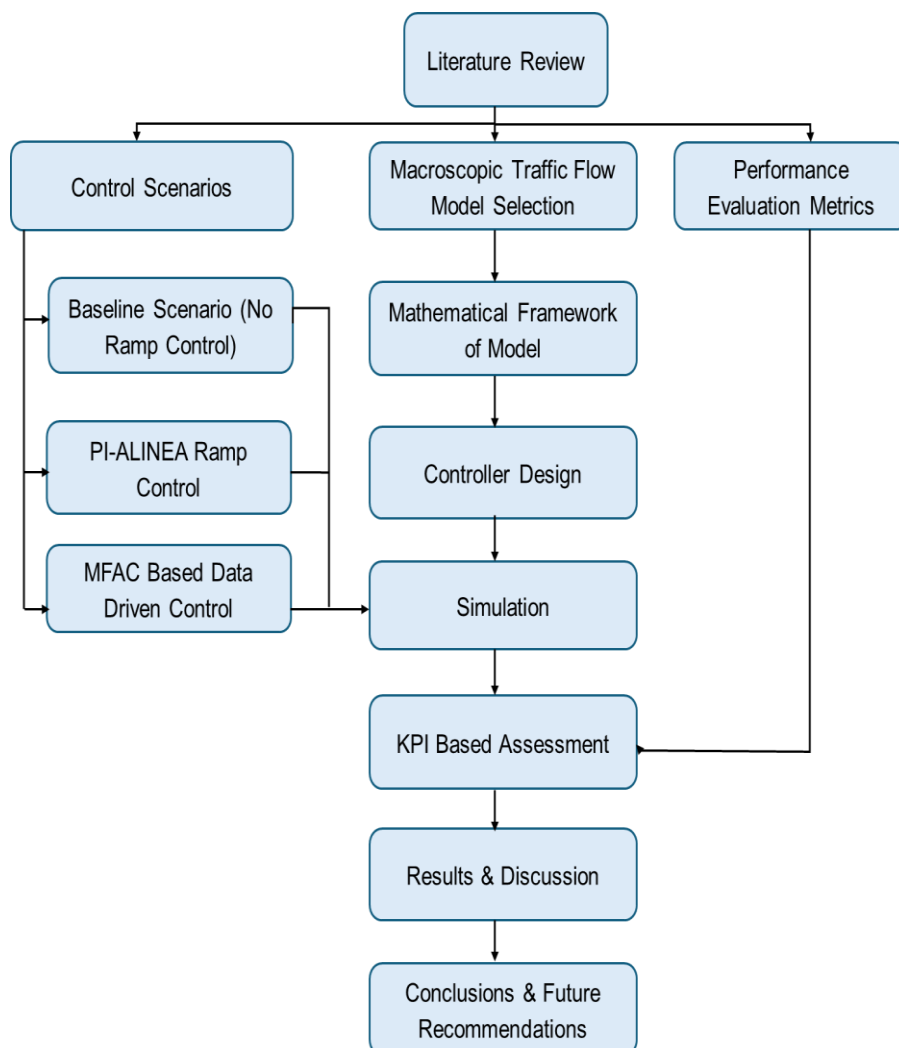


Figure 1: Methodology Overview

- Three control scenarios evaluated using METANET macroscopic simulation model.
- Performance assessed using indicators Total Time Spent (TTS) and Total Travel Time Delay. (TTD)

### 4. Simulation Setup

- Freeway divided into multiple sections.
- Time-varying ramp demand applied to induce congestion.

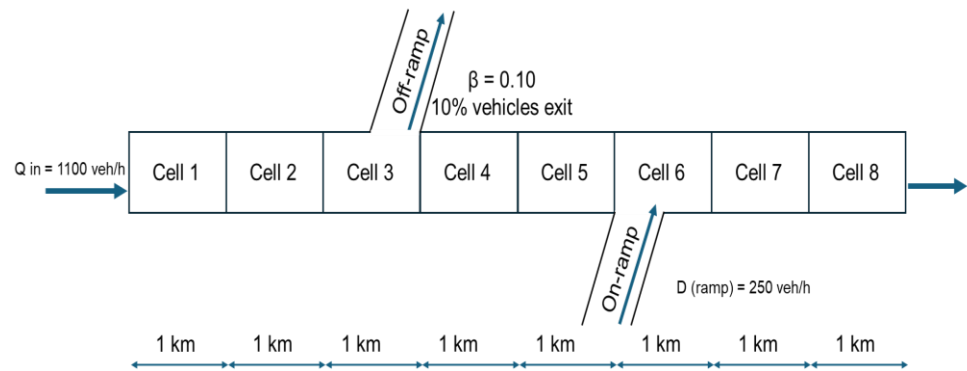


Figure 2: Freeway Layout

### 5. Results & Analysis

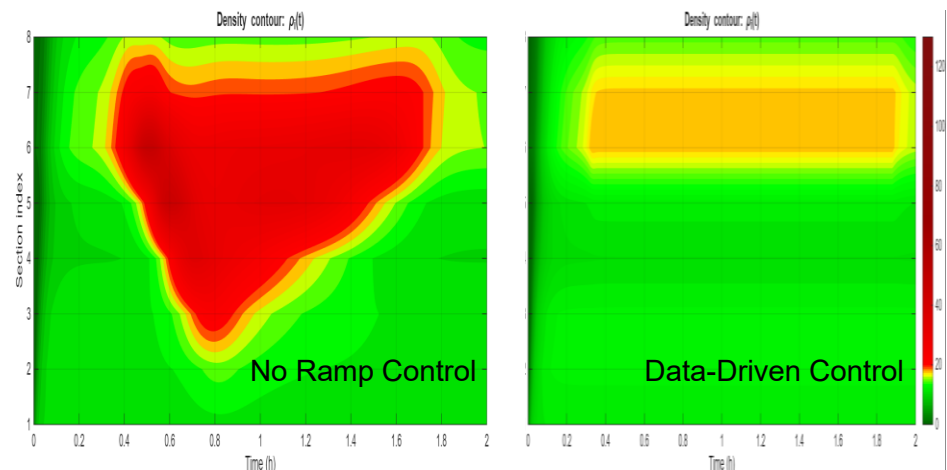


Figure 3: Impact of Data Driven Control on Density

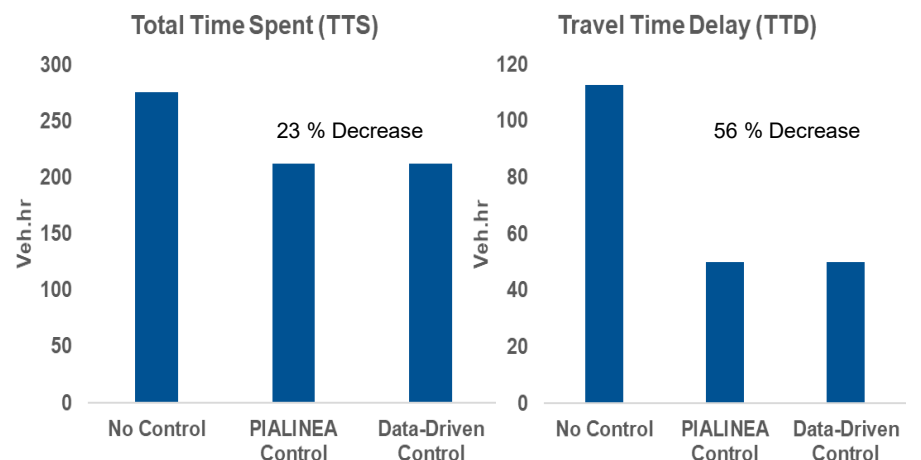


Figure 4: KPI's Based Assessment

### 6. Conclusions & Recommendations

- MFAC showing performance like PI-ALINEA without an explicit model validates its capability to adapt to uncertain traffic conditions without compromising performance.
- Proposed data driven approach offers a more flexible and robust alternative for freeway ramp control.
- In future the approach should be validated using real traffic data.
- Extension of the study to multi-ramp coordination and integration with Variable Speed Limit (VSL) is proposed.