U.S. Department of Transportation
Federal Highway Administration
Office of Operations
Research and Development

Characterizing the Impact of Production Adaptive Cruise Control on Traffic Flow: An Investigation

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Turner-Fairbank Highway Research Center

Introduction

- ACC utilizes radar to maintain desired constant time gap
- ACC capability in vehicles is on the rise
  - 2.2% of new 2014 models[1]
  - 7.2% of new 2020 models[1]
- ACC is a convenience feature
- ACC throughput estimations in literature are highly variable

Contribution Statements

- This paper seeks to serve as a comprehensive assessment of the likely impact of ACC on traffic flow.
- Four ACC car-following models are simulated using VISSIM's External Driver Model functionality under consistent simulation conditions[2,3,4,5].
- Models are (re)calibrated using car-following data from two of the FHWA ACC-equipped 2013 Cadillacs SRXs[6].
- Corridor throughput and traffic flow characteristics are explored in detail.

ACC Car-Following Models (CFMs)

- MIXIC[2,7]
  - One of the original models for automated highway systems
  - Highly unstable - lacks a collision warning system (CWS)
- Improved Intelligent Driver Model (IIDM)[3]
  - Originally developed for naturalistic driving
  - Additional heuristics added to IIDM for ACC
  - Collision free (without human takeover)

ACC Car-Following Models (CFMs)

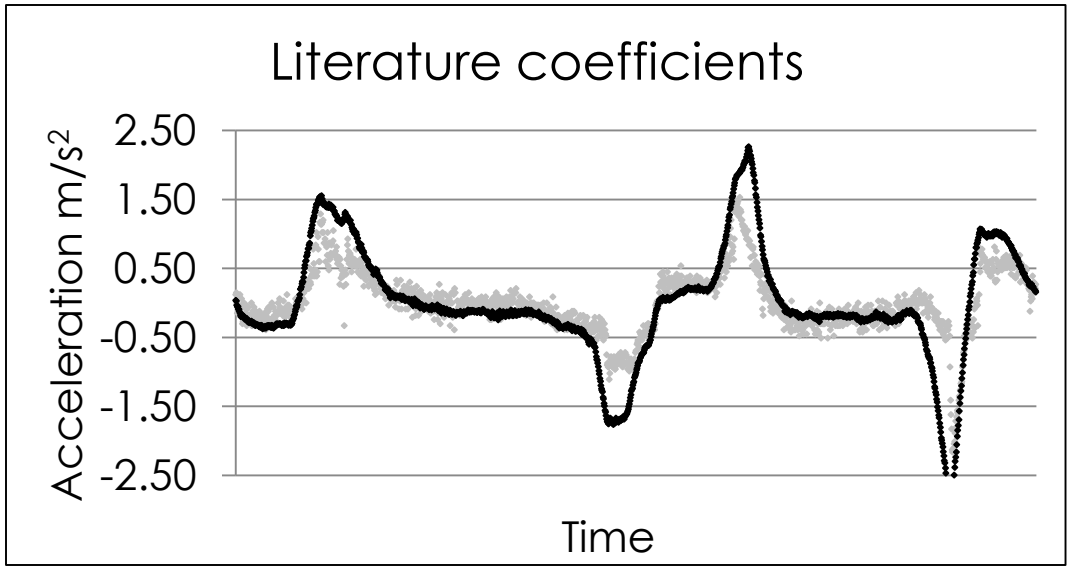
- California PATH Empirical Model[4]
  - Includes regression model for a CWS developed by CAMP
  - Calibrated using data collected from ACC-enabled Infiniti M56s
- TU Delft Empirical Model[5]
  - Based on PATH algorithm
  - Includes approach mode and dynamic spacing margin
  - Includes logistic model for CWS developed by CAMP

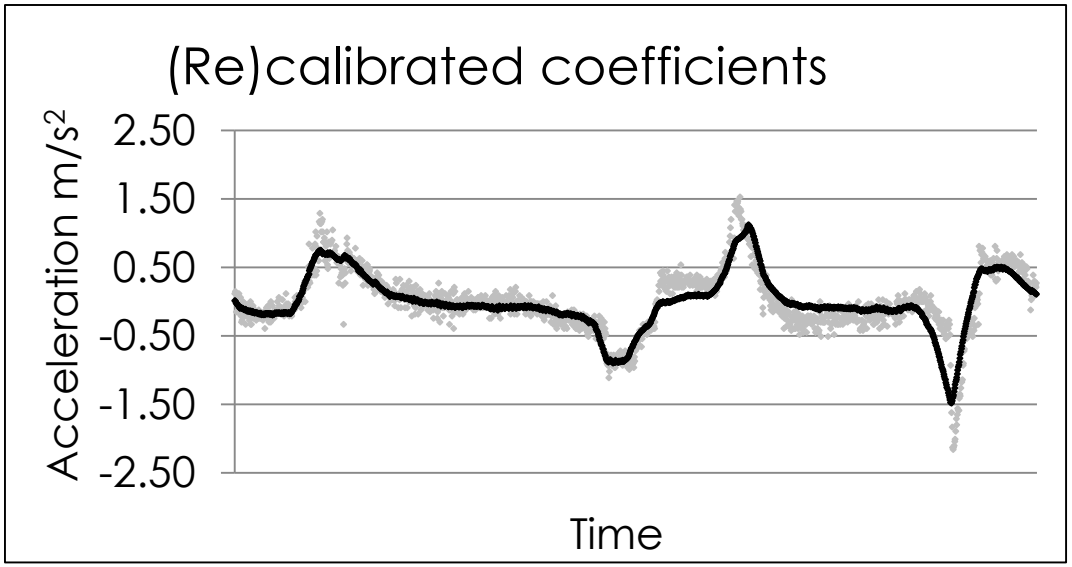
(Re)calibration of ACC CFMs

- Data collected July 2015
- Dulles Access Road, Northern Virginia
- 2013 ACC-enabled Cadillac SRXs
- Acceleration/Deceleration scenarios between 25-75mph
- Calibration optimization problem:
  - Minimize RMSE between observed and predicted acceleration
  - Split into calibration and validation dataset

Calibration Coefficients

Model	Calibration coefficients	Purpose of coefficient	Original coefficients found in literature	(Re)calibrated coefficients using Cadillac SRX data
MIXIC	k_v	Sensitivity to difference in relative velocity	0.58	0.27
	k_d	Sensitivity to difference in physical gap and reference distance	0.10	0.06
IIDM	a	Represents maximum acceleration	1.96	1.00
	b	Represents maximum deceleration	2.94	2.55
PATH	k_1	Sensitivity to distance error	0.23	0.07
	k_2	Sensitivity to speed error	0.07	0.27
Delft	k_1	Sensitivity to distance error	0.23	0.02
	k_2	Sensitivity to speed error	0.07	0.33


Literature coefficients
Acceleration m/s2
2.50
1.50
0.50
-0.50
-1.50
-2.50
Time


(Re)calibrated coefficients
Acceleration m/s2
2.50
1.50
0.50
-0.50
-1.50
-2.50
Time

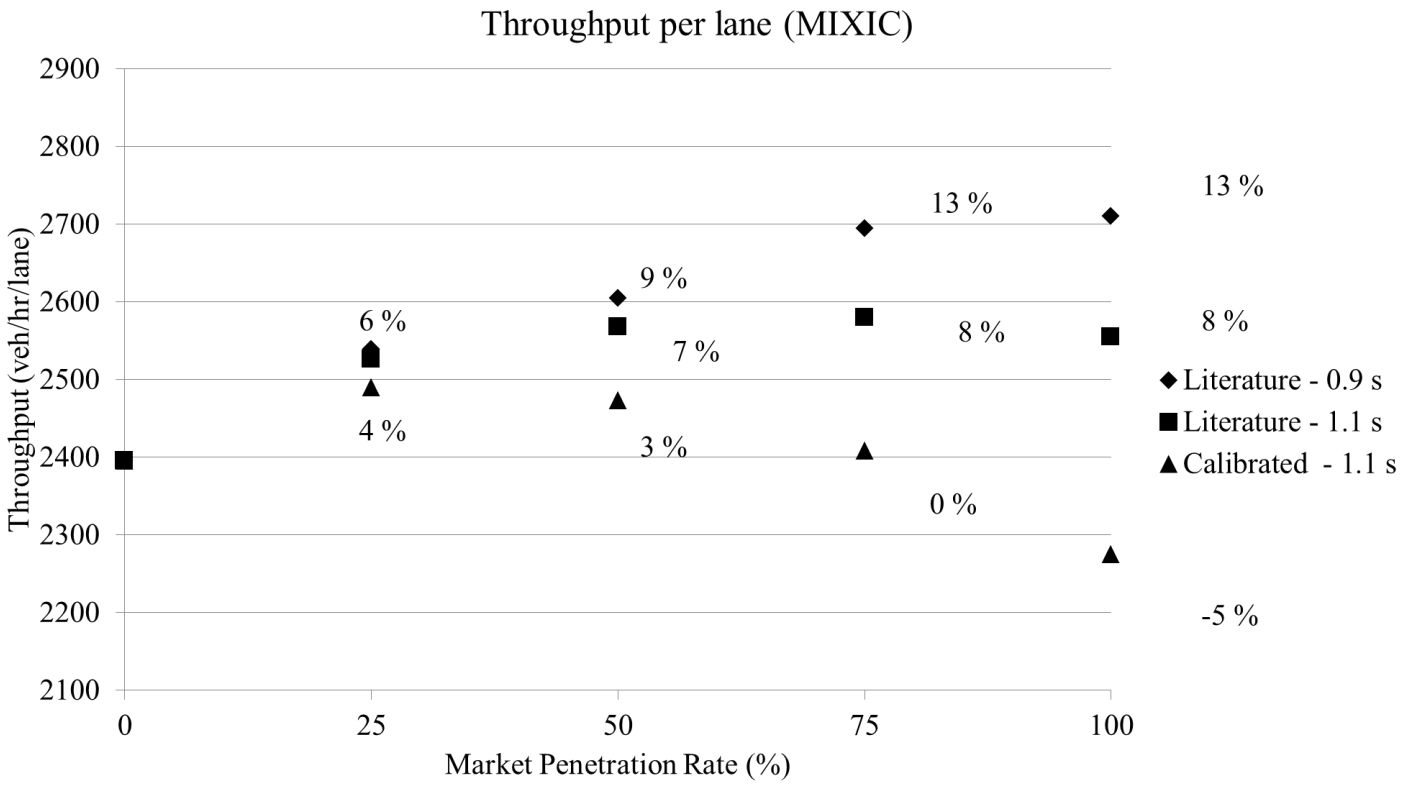
Microsimulation Case Studies

- Vehicle Control
  - ACC CFM – longitudinal control
  - Software lane changing logic – lateral control
  - Human takeover as prescribed by ACC CFM
- Assumptions:
  - MP rates | [0%–100%], 25%
  - Time gaps | [0.9s, 1.1s]
  - Desired speed distribution – [55-65mph]
  - Ten random seeds[9]

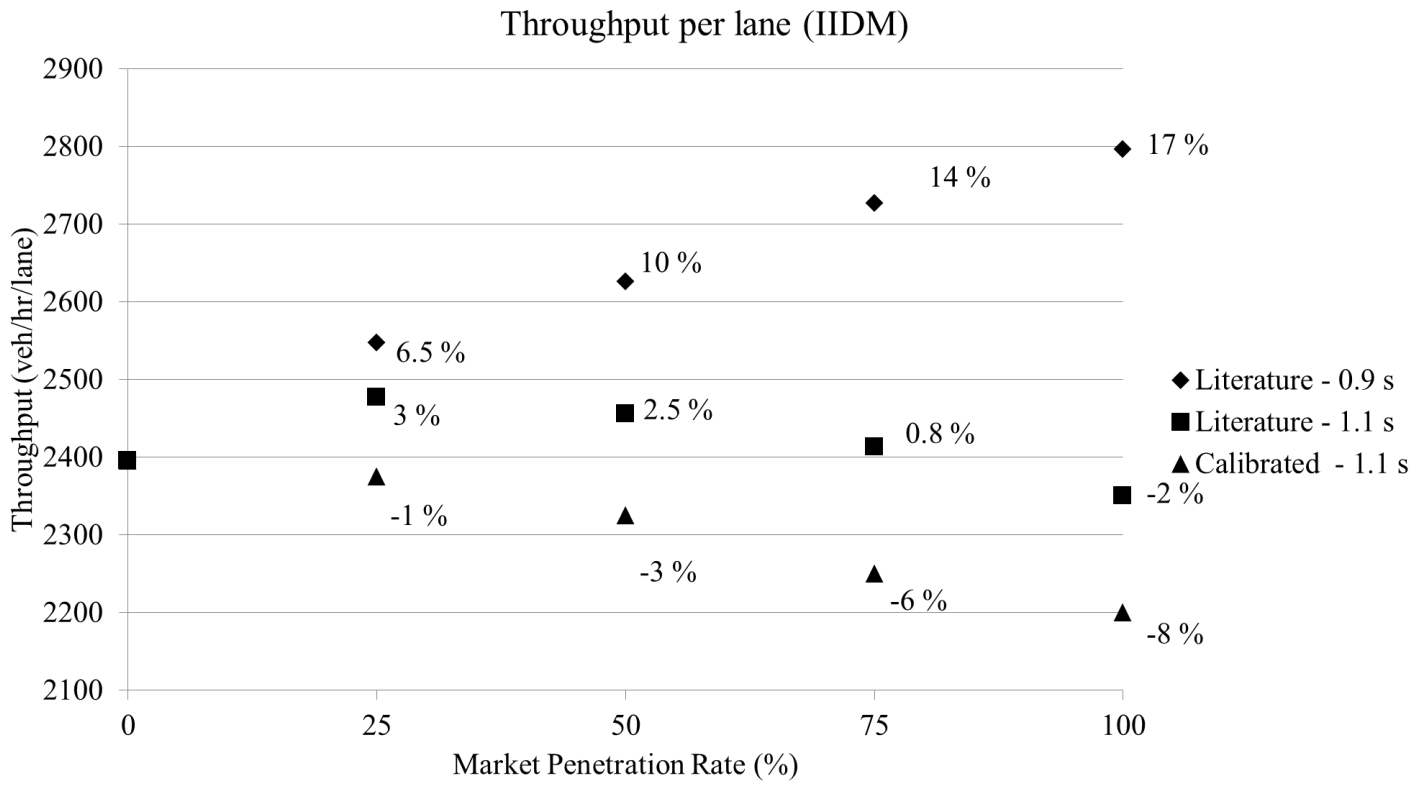
Microsimulation Case Studies

- Throughput Analysis
  - Four lane basic segment
  - Demand | [1800–3000vphpl], 200vphpl
  - Over 4200 simulations
- Traffic Flow Characteristics Analysis
  - Three lane basic segment
  - Random reduced speed zones to induce bottlenecks[8]
    - Upstream of emulator – congested regime
    - Downstream of emulator – uncongested regime

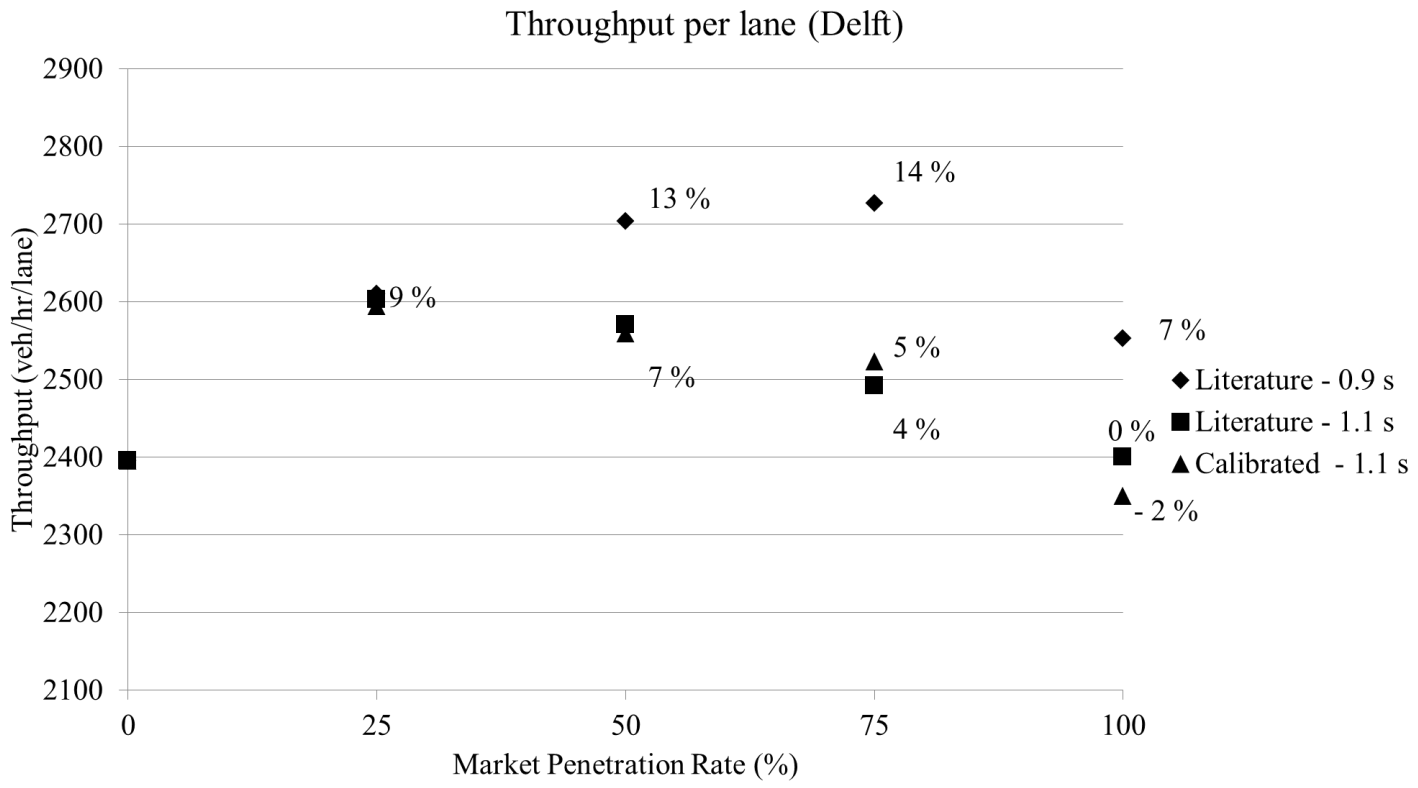
Throughput Analysis - MIXIC



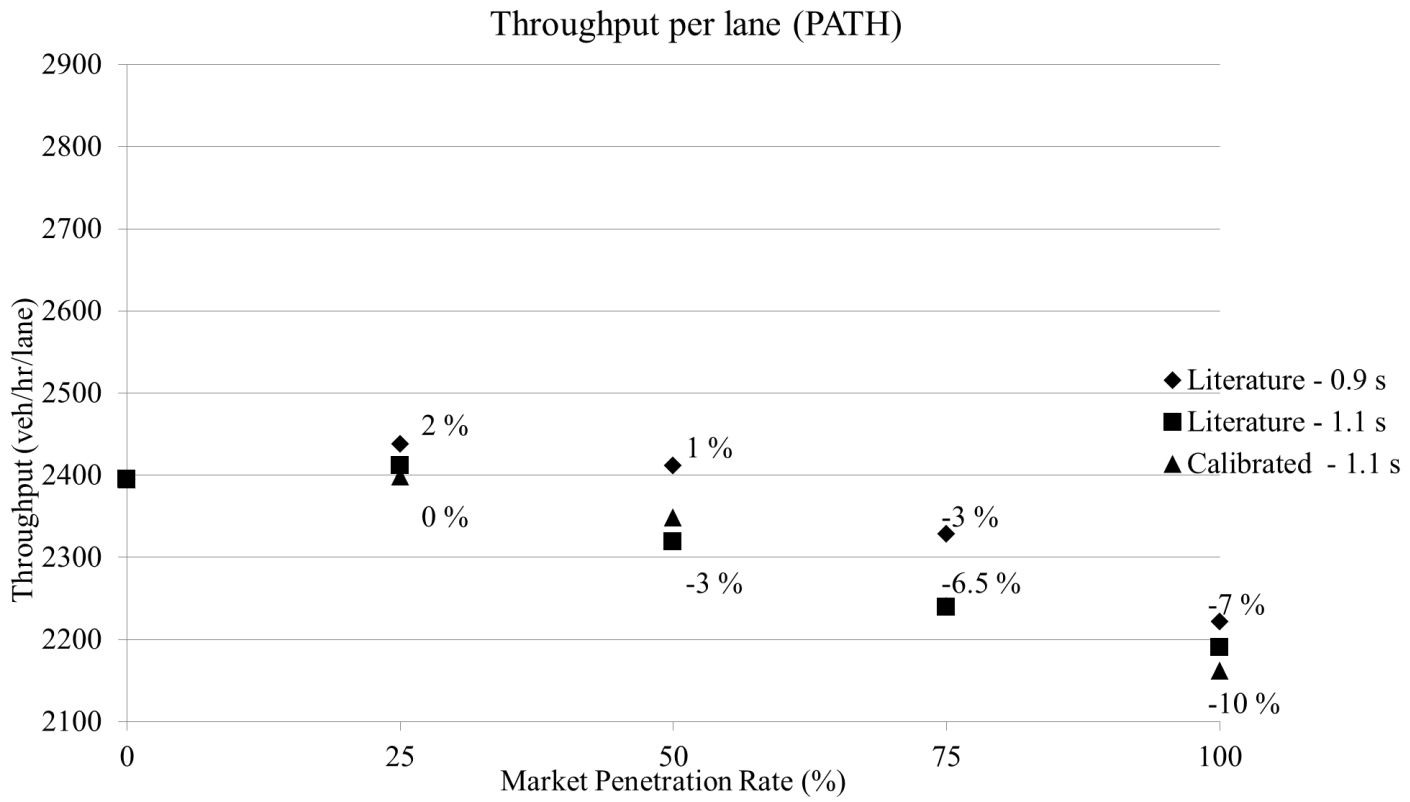
Throughput Analysis - IIDM

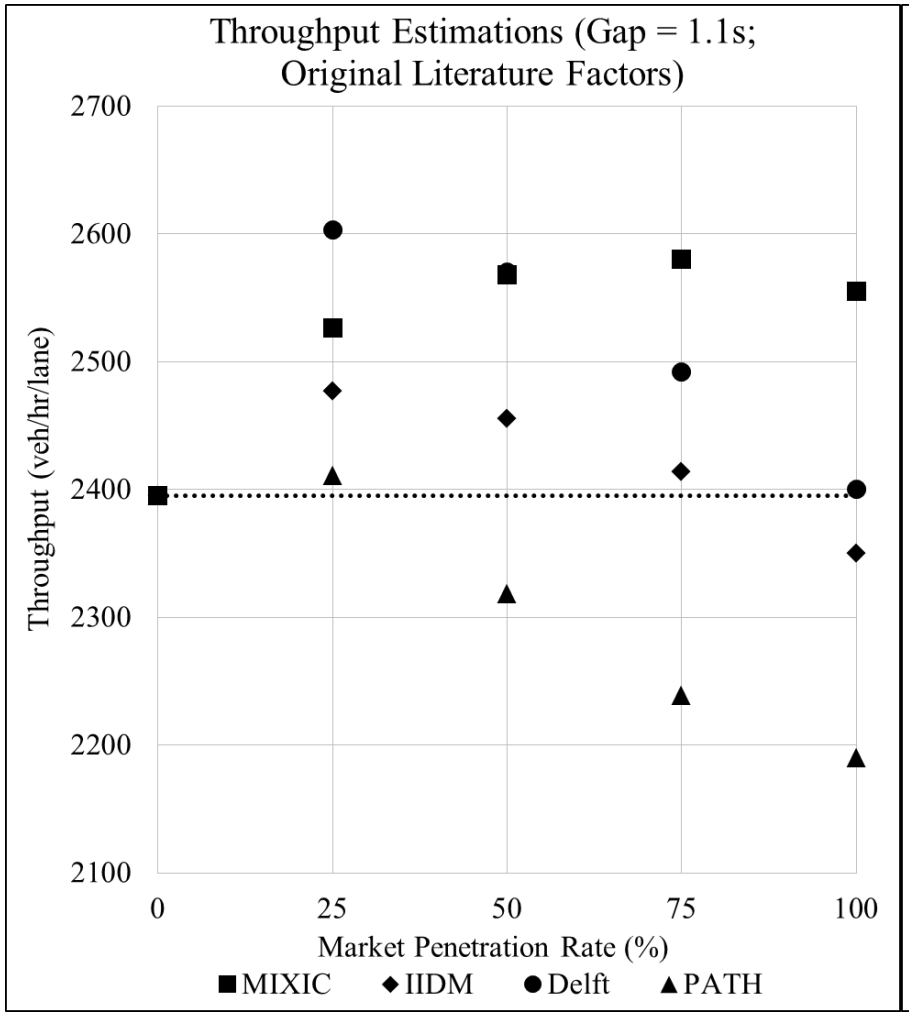


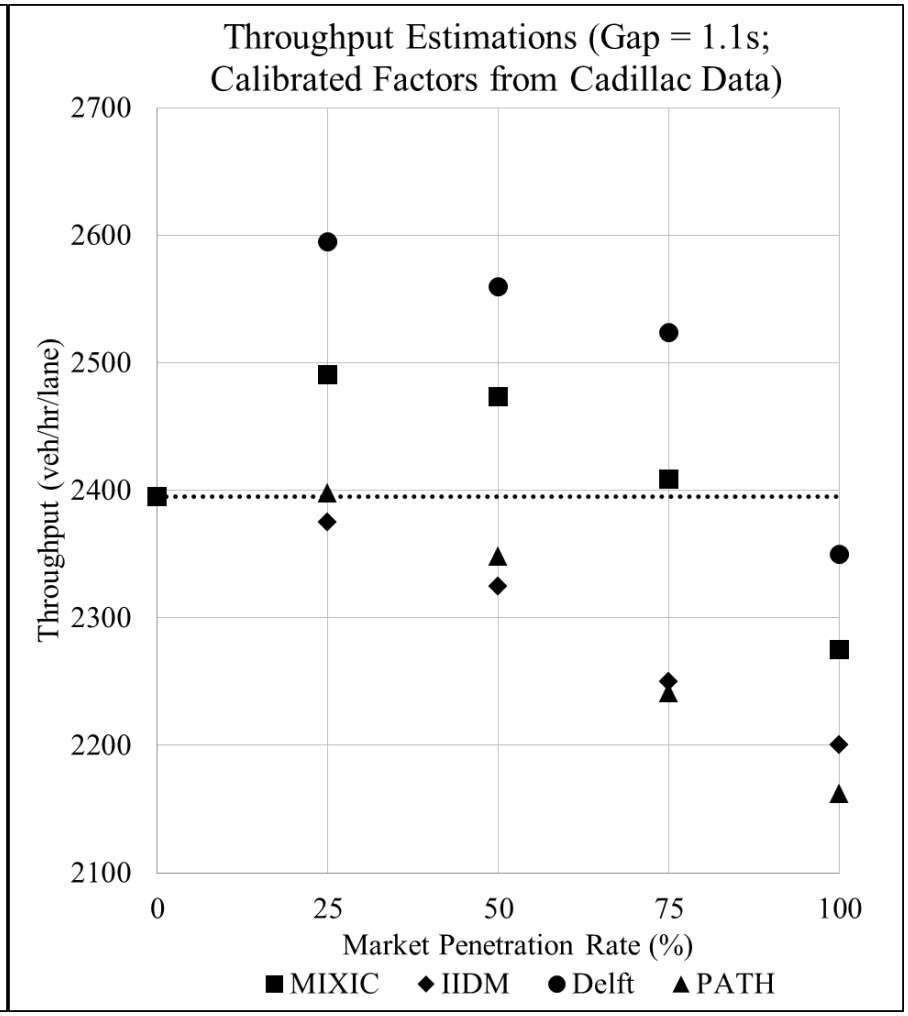
Throughput Analysis - Delft



Throughput Analysis - PATH

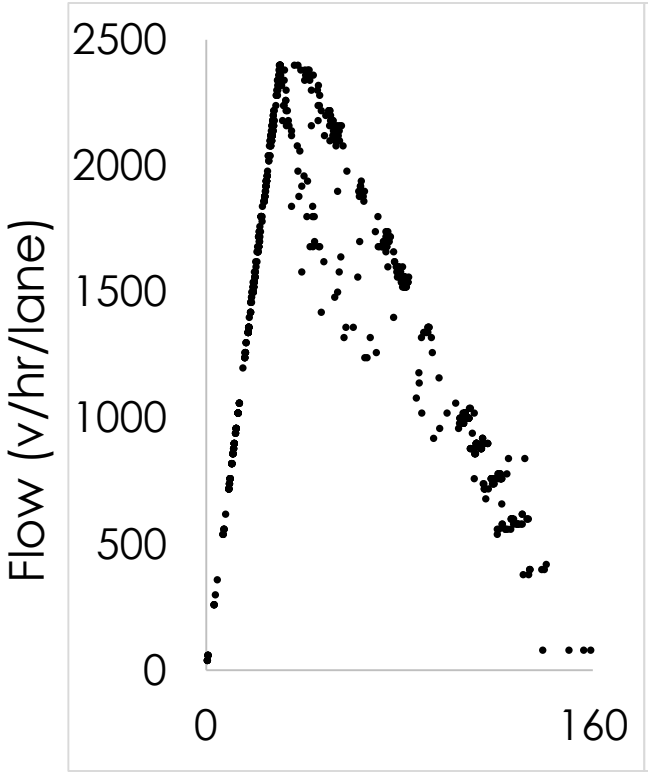



Throughput Estimations (Gap = 1.1s;
Original Literature Factors)
Throughput (veh/hr/lane)
2700
2600
2500
2400
2300
2200
2100
0
25
50
75
100
Market Penetration Rate (%)
MIXIC
IIDM
Delft
PATH

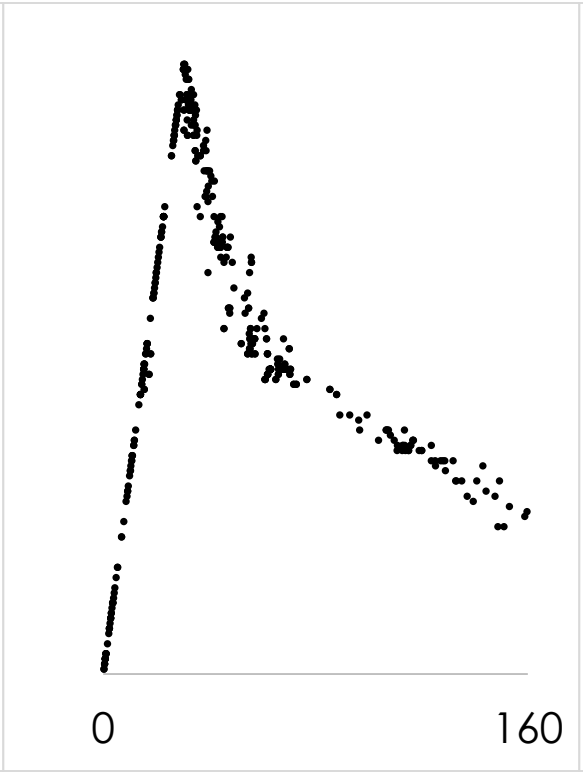

Throughput Estimations (Gap = 1.1s;
Calibrated Factors from Cadillac Data)
Throughput (veh/hr/lane)
2700
2600
2500
2400
2300
2200
2100
0
25
50
75
100
Market Penetration Rate (%)
MIXIC
IIDM
Delft
PATH

Assuming 100% MP

IIDM Fundamental Diagram



Delft Fundamental Diagram



PATH Fundamental Diagram

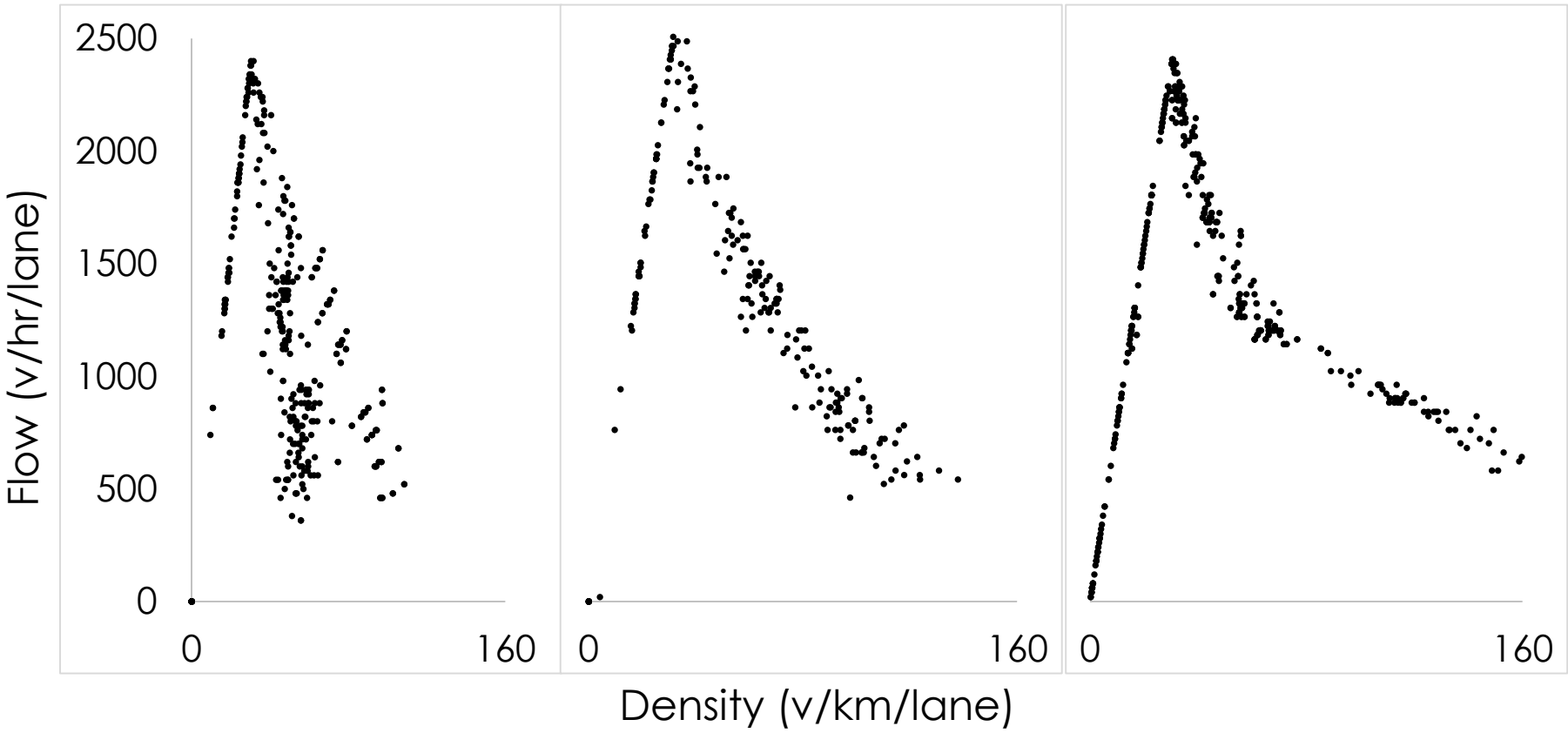
Flow (v/hr/lane)

Density (v/km/lane)

Delft 0% MP

Delft 50% MP

Delft 100% MP



Conclusions

- The MIXIC ACC CFM is most sensitive to calibration coefficients
- The IIDM ACC CFM is most sensitive to the desired time gap
- The PATH & Delft empirical ACC CFM not sensitive to coefficients
- When ACC MP rates are low, throughput ↑
- Marginal impact on throughput when MP rate ≤ 50%
- When MP rates > 50%, average throughput ↓
- Scatter in the fundamental diagram ↓ as MP ↑
- Congested regime of FD is sensitive to the ACC CFM (human takeover alters shape)

Thank you for your attention. Any questions?

For additional information, please contact Dr. Joe Bared at Joe.Bared@dot.gov

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