AUTONOMOUS VEHICLES ON ARTERIAL STREETS AND INTERSECTIONS - A SIMULATION ANALYSIS

Corresponding Author:  
Yayun (Allen) Wang, P.E.

Co-Authors:  
Sai Sirandas, P.E.  
David Stanek, P.E.

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OUTLINE.

1. Overview
2. Simulation Parameters
3. Case Studies
4. Findings
OVERVIEW.

Why study this?

Purpose:

• Using calibrated existing traffic models to evaluate potential effects of autonomous vehicles (AVs) on city streets where the traffic flow is interrupted by signals and the roadway space is shared with other modes of travel.

• While the exact driving behavior and adoption timeline is uncertain, this study conducts sensitivity tests to examine the effects across a range of AV driving behavior and various market penetration rates.
OVERVIEW.

How do we study this?

Approach:

- **Tool:** Vissim Microsimulation Software developed by PTV Group

- **Approach:** Use an “autonomous vehicle driver behavior” in three calibrated simulation models

- **Data Source:** Driving behavior parameters estimated from previous research and Vissim’s built-in autonomous vehicle driving logic
Key Parameters:

- **SAE Level 5 Autonomy:** Full autonomy that does not require any human control
- **Consistent AV Driving Behavior:** All AVs have the same driving behavior
- **Travel Demand:** Induced demand is not accounted for in this analysis
- **Signal Timing:** Base traffic signal timings remain unchanged
- **Roadway Space:** No dedicated AV lanes or reallocation of roadway space
- **AV Fleet Size:** Vehicle size remains the same as today

This analysis focuses on the effects of driving behavior and penetration rates, therefore parameters listed above are held constant...They can be adjusted and tested as the primary variable.

SAE: Society of Automotive Engineers
PARAMETERS.
Simulation model inputs

Driving Behavior Research

- Car-following Behavior
- Detection & Reaction to Signals
- Interaction with Non-motorists
- V2I Communication
- V2V Communication

Note: V2I and V2V communication is simplified in this analysis, modeled as reaction time, start-up time, and fluctuation in speeds.
**PARAMETERS.**

Simulation model inputs

**Human Drivers**

Existing conditions: driving behavior of average human drivers.

**AV: Conservative**

Potential near-future AV scenario with some operating parameters being more conservative than human drivers, while other parameters being similar or slightly improved with more advanced technology.

**AV: Moderate**

Most operating parameters are similar to average human drivers but are more consistent; some parameters are improved due to more advanced technology.

**AV: Optimal**

Operating scheme with reduced headways, clearance distances, improved vehicle dynamics and communication capabilities. All parameters are improved from existing conditions.

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CASE STUDIES

Where are the study locations?

**Case Study 1**
Multimodal Intersection

- Intersection in Santa Clara County, CA
- F&P AV parameters
- 4 AV scenarios
- Suburban office complex
- Signalized intersection
- Heavy bike/ped/bus activity

**Case Study 2**
Undersaturated Corridor

- El Camino Real, Palo Alto, CA
- Vissim built-in AV parameters
- 15 AV scenarios
- Retail use
- Two-mile multi-lane arterial
- 6 signalized intersections

**Case Study 3**
Oversaturated Corridor

- SR-29, American Canyon, CA
- Vissim built-in AV parameters
- 15 AV scenarios
- Five-mile two-lane rural highway
- 7 signalized intersections

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CASE STUDIES.

Case Study #1: Multimodal Intersection

Travel modes:
- Passenger vehicles
- Buses/shuttles
- Cyclists
- Pedestrians

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<tr>
<th>Simulation Scenarios</th>
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<td>Scenario</td>
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CASE STUDIES

Case Study #1: Multimodal Intersection

Network Person Delay (person-hours)

- Human-driven: 233
- Conservative @ 50%: 287 (23% increase)
- Moderate @ 70%: 214 (-8% decrease)
- Moderate @ 100%: 183 (-23% decrease)
- Optimal @ 100%: 128 (-45% decrease)
CASE STUDIES.

Case Study #2: Undersaturated Corridor

**El Camino Real** in Palo Alto, CA

- Two-mile arterial: 6 signalized intersections
- 15 Scenarios:
  - 3 AV Behaviors X 5 Penetration Rates
CASE STUDIES

Case Study #2: Standstill Conditions at Signal

25% Optimal AVs

50% Conservative AVs

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CASE STUDIES

Case Study #2: Undersaturated Corridor

Video Clip #1

Autonomous Vehicles on Arterial Streets and Intersections
CASE STUDIES.

Case Study #2: Undersaturated Corridor

Video Clip #2

25% Optimal AVs

50% Conservative AVs

Page Mill Rd

Parrage Ave

Autonomous Vehicles on Arterial Streets and Intersections
**CASE STUDIES**

**Case Study #2: Undersaturated Corridor**

*El Camino Real (Palo Alto)*

Average Network Delays - PM Peak Hour

- **AVs - Conservative**
- **AVs - Moderate**
- **AVs - Optimal**
- **Baseline**

- **Average Delay (seconds)**
- **% AV Share**

Graph showing the comparison of average network delays for different scenarios. The graph indicates the impact of autonomous vehicles (AVs) on delay times, with conservative, moderate, optimal, and baseline scenarios compared. The baseline scenario shows significantly higher average delays compared to AV scenarios, with a 233% increase in delay, while the optimal scenario shows a 24% decrease in delay compared to the baseline.
Case Studies

Case Study #3: Oversaturated Corridor

SR-29 in American Canyon, CA

- A five-mile stretch of rural highway
  - 7 signalized intersections
- A heavily congested arterial with congestion spanning multiple hours
- 15 Scenarios:
  - 3 AV Behaviors X 5 Penetration Rates
CASE STUDIES

Case Study #3: Oversaturated Corridor

SR-29 (American Canyon)

Average Network Delays - PM Peak Hour

- AVs - Conservative
- AVs - Moderate
- AVs - Optimal
- Baseline

Average Delay (seconds)

% AV Share

Baseline: +167%
AVs - Optimal: -61%
FINDINGS.

Analysis summary

Fleet penetration and driving behavior of AVs significantly affect roadway operations and infrastructure capacity:

• Potential to experience more congestion in the near-future as AVs behave more conservatively than human drivers

• As AVs mature and become a larger portion of the fleet, they could utilize existing infrastructure more efficiently and result in additional capacity
FINDINGS.

While AVs continue to evolve and regulations are being developed, there are a lot of unknowns regarding how AVs would behave and the corresponding effects on the transportation system.

Take a scenario-planning approach to evaluate potential effects of AVs and make recommendations and decisions that are resilient to the wide range of possible outcomes.

Potential Future Applications:

- Effect of change in vehicle fleet size
- Effect of mixed AV behavior (i.e. AVs made by different manufactures)
- Effect of dedicated AV lanes
- More complex V2V and V2I algorithms
  - Vissim + COM, Python or external driver module
- Effect of induced travel
- Curbside utilization and management
Thank you for your time.

For more information, please contact:

**Yayun (Allen) Wang, P.E.**
Senior Transportation Engineer
Phone (408) 556-9215
a.wang@fehrandpeers.com

**Sai Sirandas, P.E.**
Senior Transportation Engineer
Phone (415) 659-9267
s.sirandas@fehrandpeers.com

**David Stanek, P.E.**
Associate
Phone (916) 329-7332
d.stanek@fehrandpeers.com


