Performance Analyses of Information Based Managed Lane Choice Decisions in a Connected Vehicle Environment

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Introduction

• Research on Managed Lane Users
  – Travel time distribution of drivers
  – Overestimated travel time savings

• Research on Connected Vehicles (CVs) and Connected Autonomous Vehicles (CAVs) on MLs
  – Usage of dedicated lanes at different market penetration rates (MPRs)

• Humans are still the decision makers
  – Reactions to re-routing information

• Model how drivers in CVs make lane choice decisions based on information provided by ML system

• Question how will traffic perform in a CV environment
Research Overview

• Model a ML system with
  – Different CV market penetration rates (i.e. 0%, 10%, 50%, 100% MPRs)
  – Information (i.e. travel time savings) per 5-minute
  – Lane choice decisions based on individual’s value of travel time

• Evaluate potential impacts on
  – Throughput
  – Average delay per vehicle
  – Travel speed
  – Travel time saving (TTS) = Travel time_{GPL} - Travel time_{ML}
  – Percentages of vehicles in MLs vs. GPLs
  – Changes in revenue
Katy Freeway (Houston, Texas)

- Length of segment = 10 miles
- Speed limit = 60 mph
- 5 GPLs & 2 MLs
- Toll rate at PM peak
  - Wirt Toll Plaza: $1.9
  - Wilcrest Toll Plaza: $1.9
  - Eldridge Toll Plaza: $3.2
Field Collected Volume Inputs

5-min Vehicle Count* on Katy Freeway

<table>
<thead>
<tr>
<th>Lane Type</th>
<th>Total Number of Vehicle (veh/period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPL</td>
<td>11,214</td>
</tr>
<tr>
<td>ML</td>
<td>5,394</td>
</tr>
<tr>
<td>Total</td>
<td>16,608</td>
</tr>
</tbody>
</table>

*PM Peak Traffic Period

*December 2018, From TxDOT and Texas A&M Transportation Institute
# Income Groups and Trip Types


<table>
<thead>
<tr>
<th>Trip Type</th>
<th>Income Group</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary</td>
<td>Low</td>
<td>17.50%</td>
<td>25.90%</td>
<td>26.60%</td>
</tr>
<tr>
<td>Important Appointment</td>
<td>Low</td>
<td>1.88%</td>
<td>2.78%</td>
<td>2.85%</td>
</tr>
<tr>
<td>Late for Appointment</td>
<td>Low</td>
<td>1.88%</td>
<td>2.78%</td>
<td>2.85%</td>
</tr>
<tr>
<td>Need to Arrive On Time</td>
<td>Low</td>
<td>1.88%</td>
<td>2.78%</td>
<td>2.85%</td>
</tr>
<tr>
<td>Plan Trip Considing ML</td>
<td>Low</td>
<td>0.94%</td>
<td>1.39%</td>
<td>1.43%</td>
</tr>
<tr>
<td>Need to Arrive On Time With Extra Stops</td>
<td>Low</td>
<td>0.94%</td>
<td>1.39%</td>
<td>1.43%</td>
</tr>
</tbody>
</table>
## Value of Travel Time Distribution


<table>
<thead>
<tr>
<th>Trip Type</th>
<th>Income Group</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary</td>
<td></td>
<td>7.95 - 7.95(t_{time})</td>
<td>7.38 - 7.38(t_{time})</td>
<td>8.62 - 8.62(t_{time})</td>
</tr>
<tr>
<td>ImportantAppointment</td>
<td></td>
<td>18.95 - 18.95(t_{time})</td>
<td>16 - 16(t_{time})</td>
<td>23.23 - 23.23(t_{time})</td>
</tr>
<tr>
<td>LateforAppointment</td>
<td></td>
<td>35.09 - 27.17(t_{time})</td>
<td>27.76 - 21.5(t_{time})</td>
<td>47.69 - 36.92(t_{time})</td>
</tr>
<tr>
<td>NeedtoArriveOnTime</td>
<td></td>
<td>25.03 - 17.08(t_{time})</td>
<td>21.65 - 14.85(t_{time})</td>
<td>30.43 - 20.87(t_{time})</td>
</tr>
<tr>
<td>PlanTripConsidingML</td>
<td></td>
<td>17.3 - 13.84(t_{time})</td>
<td>15.25 - 12.2(t_{time})</td>
<td>20 - 16(t_{time})</td>
</tr>
<tr>
<td>NeedtoArriveOnTime WithExtraStops</td>
<td></td>
<td>9 - 9(t_{time})</td>
<td>8.27 - 8.27(t_{time})</td>
<td>9.86 - 9.86(t_{time})</td>
</tr>
</tbody>
</table>

\(t_{time}\) is randomly drawn from a triangular distribution (-1,1) with a mean of 0.
Information Based Lane Choice

\[
VTT \times TTS \begin{cases} 
> \text{Toll} & \text{choose ML} \\
\leq \text{Toll} & \text{choose GPL}
\end{cases}
\]

where,

- \(VTT\) = Value of travel time for each vehicle
- \(TTS\) = Travel time saving from last 5-minute interval
- \(\text{Toll}\) = Toll price for the segment
System Setup

- Information Based Lane Choice
  - react
  - not react
  - ML/GPL split from field collection

Travel Time to SH6
- ML: 10 mins
- GPL: 17 mins

CV

Non-CV
Does Traffic Reflect Immediately?

Response Time

Start to Reflect Macroscopically

Start to Broadcast TTS

Number of Vehicle (veh/5-min)
How to Reduce Response Time?

- Average Travel Speed
- Collection Distance of Travel Time

Higher Speed

Shorter Collection Distance
# Overall Mobility Performance

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Total Throughput (veh/hr)</th>
<th>Average Delay (s/veh)</th>
<th>Average Travel Time (s/veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV MPR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>11776</td>
<td>120.53</td>
<td>1301.40</td>
</tr>
<tr>
<td>10%</td>
<td>11808</td>
<td>119.52</td>
<td>1290.98</td>
</tr>
<tr>
<td>50%</td>
<td>11786</td>
<td>122.95</td>
<td>1342.65</td>
</tr>
<tr>
<td>100%</td>
<td>11766</td>
<td>129.12</td>
<td>1389.86</td>
</tr>
</tbody>
</table>

- Measurements similar up to ~7% increases
Time Interval: 17:40 – 17:45

<table>
<thead>
<tr>
<th></th>
<th>0% CV MPR</th>
<th>10% CV MPR</th>
<th>50% CV MPR</th>
<th>100% CV MPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reacted CV &amp; Chosed GPL</td>
<td>0</td>
<td>40</td>
<td>201</td>
<td>405</td>
</tr>
<tr>
<td>Reacted CV &amp; Chosed ML</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>
Time Interval: 17:40 – 17:45

Number of Vehicle

Average Travel Time

ML
GPL

0%
10%
50%
100%

Number of vehicle (veh)

CV MPR

Average Travel Time (s/veh)

ML
GPL

0%
10%
50%
100%

0
100
200
300
400
500
600
700
800

0%
10%
50%
100%

800.00
900.00
1000.00
1100.00
1200.00
1300.00
1400.00
1500.00

897.76
897.93
877.72
869.69

1385.05
1387.28
1401.01
1408.53

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Decrease in Use of MLs

0% CV MPR

10% CV MPR

- Vehicle Percentage on GPLs (%)
- Vehicle Percentage on MLs (%)

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Decrease in Use of MLs

0% CV MPR

50% CV MPR

Vehicle Percentage on GPLs (%)  
Vehicle Percentage on MLs (%)
Decrease in Use of MLs

0% CV MPR

100% CV MPR

Vehicle Percentage on GPLs (%)  Vehicle Percentage on MLs (%)
Estimated Loss in Revenue

<table>
<thead>
<tr>
<th>CV MPR</th>
<th>Loss ($) per weekday</th>
<th>Total Loss ($) per year (261 weekdays)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10%</td>
<td>$(224)</td>
<td>$(58,412)</td>
</tr>
<tr>
<td>50%</td>
<td>$(6,905)</td>
<td>$(1,802,283)</td>
</tr>
<tr>
<td>100%</td>
<td>$(12,289)</td>
<td>$(3,207,507)</td>
</tr>
</tbody>
</table>

17.4% loss in revenue compared to the revenue in 2017 with an assumption of 0% CV MPR
Findings

• Information exchange was assumed instantaneous between vehicles to system, but there existed a time delay in the macroscopic traffic reflection.

• Decrease in use of MLs with a higher CV MPR.

• Since drivers perceive they are saving more travel time than they actually do save, it may not be in the MLs best interest to share travel time saving information with drivers.
Limitations

- Assumption of only 40% CV drivers reacted to a provided information.
- Fixed percentages are assigned to income levels and urgencies of trips based on the literature.
- All performance analyses are based on VISSIM simulation outputs.
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