Comparisons of Mandatory and Discretionary Lane Changing Behavior on Freeways

Matthew Vechione, Esmaeil Balal, and Ruy Long Cheu
The University of Texas at El Paso

Background
- A lane change is a lateral movement of a vehicle which is always accompanied with a longitudinal movement.
- A lane changing event involves up to five vehicles (see S, FB, PB, FA, PA in the figure below).
- A lane change may be modeled as a four-step process: (1) motivation; (2) selection of target lane; (3) checking for opportunity to move; and (4) the actual move.
- This research focuses on step (3).
- There are two types of lane changes on freeways: mandatory and discretionary.
- A Mandatory Lane Change (MLC) occurs when a driver must change lanes to exit a freeway, avoid a lane closure downstream, turn at a downstream intersection, etc.
- A Discretionary Lane Change (DLC) occurs at a driver’s own discretion for faster speed, greater following distance, further line-of-sight, etc.
- A driver is expected to have different decision rules and/or risk-taking behavior for the two types of lane changes.

Objectives
The objectives of this research are to:
1. Examine descriptive statistics for variables that describe vehicle interactions for MLCs and DLCs, respectively.
2. For each variable, conduct hypothesis test on the difference between the means of MLCs and DLCs.
3. For each variable, apply the Kolmogorov-Smirnov (KS) test to test the difference in the observed cumulative probability distributions between MLCs and DLCs.
4. For each variable, fit the probability distributions to the MLC and DLC data respectively, and use the KS test to test the difference between the fitted probability distributions.

Literature Review
- Based on a survey from 443 drivers in El Paso, TX by Balal et al. (2014), the top four input parameters were gaps and distances, as shown in the figure below.

Methodology
- Only passenger cars selected as subject vehicles;
- Vehicles that changed lanes between lanes 5 and 6 were assumed to make a DLC;
- Lane 1 omitted, as it is a HOV lane;
- For each subject vehicle, the time t when the lane changing event occurred was taken as time when the front center of the subject vehicle crossed the lane markers;
- Variable values were calculated at t-0.4, t-0.3, t-0.2, t-0.1, and t seconds, and the average values from t-0.4 to 1 second were used as the representative values.
- The averaging of data to 0.5 second intervals was to:
  i. Reduce error caused by instantaneous values in the NGSD data;
  ii. Be more consistent with human perception time; and
  iii. Be consistent with other research that used NSGSD data.

Statistical Analyses
1. Descriptive Statistics
- Dataset A

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (MLC)</th>
<th>Mean (DLC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Gap</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Rear Gap</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Distance</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

2. Difference Between Two Means
- Dataset A

<table>
<thead>
<tr>
<th>Variable</th>
<th>t Value</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Gap</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Rear Gap</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Distance</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

3. Observed Distributions
- The KS test compares a cumulative distribution against the theoretical cumulative distribution or two cumulative distributions against one another.
- The maximum difference between the two distributions is computed by:
  \[ d_{max} = \max |F(x) - G(x)| \]
- d is compared to a critical value \( d_{crit} \), where \( n_1 \) and \( n_2 \) are the sample sizes of the two distributions, \( \alpha \) is the KS test parameter with level of significance = \( \alpha \).

Conclusions
- All variables may be described by the log-normal distribution.
- There is no significant difference between MLC and DLC for the three variables in the target lane (i.e., \( d_{crit} \) and \( D \)).
- These may be common variables between MLCs and DLCs.
- For \( G_{PA} \) (in the original lane), significant differences are found between MLC and DLC.
- Population means between MLCs and DLCs in Dataset B (at 95% confidence)
- Observed probability distributions in Dataset A (at 95% confidence)
- Observed probability distributions in Dataset B (at 95% confidence)
- Fitted log-normal distributions in Dataset A (at 95% confidence)
- Fitted log-normal distributions in Dataset B (at 95% confidence)

The log-normal distribution was recommended.
- Example: log-normal distribution fitted for \( G_{PA} \) Dataset A:
- The KS test was then applied to the fitted log-normal distributions for MLC and DLC.
- Dataset A – difference between MLC and DLC
- Dataset B – difference between MLC and DLC
- Dataset A – worst case (\( G_{PA} \) in Dataset A)
- Dataset B – worst case (\( G_{PA} \) in Dataset B)