Categorizing merging and diverging strategies of truck drivers using a trajectory dataset

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Introduction

- Top 20 road sections: €210 million economic cost freight sector due to congestion
- Especially on road sections with a high percentage trucks
- Lane changing influences traffic efficiency and safety
- Objective: Identify heterogeneity in the merging and diverging behavior of truck drivers.

Top 20: economic cost freight transport

Source: INWEVA

Truck percentage

Source: INWEVA

https://www.spl.sk.ca/handbook/-/knowledge_base/drivers/changing-lanes
Approach

Data collection → Method → Test our hypothesis

Trajectory data for the Netherlands → Finite mixture modeling → Truck drivers are heterogeneous towards their merging and diverging behavior
Trajectory dataset

- Collected by helicopter method
- Ramps and weaving sections present in the Netherlands
- Open data: available online at 4TU repository

Sites

- **On-ramp**
  - Zonzeel-north: 340 m

- **Off-ramp**
  - Zonzeel-south: 230 m

- **Short weaving**
  - Klaverpolder-north: 610 m
  - Klaverpolder-south: 530 m
  - Ridderkerk-north: 740 m

- **Long weaving**
  - Princeville-east: 1000 m
  - Princeville-west: 1130 m
Method

• Finite mixture modeling
  – The overall population heterogeneity results from the underlying two or more distinct homogeneous subgroups or latent classes of individuals.
  – Expectation maximization algorithm

• Bayesian information criterion (BIC) to select the best model \( BIC = -2\ln(\text{LL}) + K \ln(n) \)
Indicator variables

• **Spatial**
  – Location of lane change initiation relative to the beginning of bottleneck

• **Temporal**
  – Lane change duration

• **Kinematic**
  – Truck driver’s speed at the instant of lane change initiation
Indicator variables

• **Gap acceptance**
  – Lead and lag gap spacing at the time of lane change initiation
  – Whether a truck driver has accepted largest available lead or lag gap spacing
  • We store all the available gaps until lane change initiation
# Data

<table>
<thead>
<tr>
<th>Merging</th>
<th>Diverging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sites</strong></td>
<td><strong>Data points</strong></td>
</tr>
<tr>
<td>On-ramp</td>
<td>50</td>
</tr>
<tr>
<td>Short weaving</td>
<td>30</td>
</tr>
<tr>
<td>Long weaving</td>
<td>48</td>
</tr>
</tbody>
</table>

**Indicator variables**

<table>
<thead>
<tr>
<th>Indicator variable</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of lane change initiation</td>
<td>Gaussian</td>
</tr>
<tr>
<td>Lane change duration</td>
<td>Gaussian</td>
</tr>
<tr>
<td>Speed at lane change initiation</td>
<td>Gaussian</td>
</tr>
<tr>
<td>Lead and lag gap spacing</td>
<td>Gaussian</td>
</tr>
<tr>
<td>Whether accepted a largest available lead/lag gap</td>
<td>Binomial</td>
</tr>
</tbody>
</table>
Results

2 types of merging strategies

3 types of diverging strategies

Segmentation is consistent over different bottlenecks
Merging strategies

- Class I truck drivers want to merge at the earliest available opportunity.
- Class II truck drivers either intentionally merge late or could not find suitable gaps initially.

<table>
<thead>
<tr>
<th>Site</th>
<th>Class I (%)</th>
<th>Class II (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-ramp</td>
<td>61.02</td>
<td>38.98</td>
</tr>
<tr>
<td>Short weaving</td>
<td>69.90</td>
<td>30.10</td>
</tr>
<tr>
<td>Long weaving</td>
<td>65.21</td>
<td>34.79</td>
</tr>
</tbody>
</table>
Diverging strategies

- Class I truck drivers initiate exit maneuvers before the beginning of a bottleneck.
- Class II truck drivers initiate exit maneuver just after the beginning of a bottleneck.
- Class III truck drivers initiate exit maneuvers a little late although gap acceptance has no role in this process.

<table>
<thead>
<tr>
<th>Site</th>
<th>Class I (%)</th>
<th>Class II (%)</th>
<th>Class III (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-ramp</td>
<td>19.30</td>
<td>46.85</td>
<td>33.85</td>
</tr>
<tr>
<td>Short weaving</td>
<td>75.00</td>
<td>7.50</td>
<td>17.50</td>
</tr>
<tr>
<td>Long weaving</td>
<td>52.89</td>
<td>32.56</td>
<td>14.55</td>
</tr>
</tbody>
</table>
Role of truck drivers to turbulence

- Lane change maneuvers in the vicinity of motorway ramps and weaving sections are primary contributors to the turbulence.
- Turbulence = number of lane changes
- Identify the role of truck drivers to the turbulence

Turbulence due to merging

- High lane changing activity (>85%) within initial 25% of ramp or weaving segment length due to class I truck drivers
Turbulence due to diverging

- High lane changing activity (>78%) within initial 25% of ramp or weaving segment length due to class I and class II truck drivers
Conclusions and future works

• Truck drivers have
  – two types of merging strategies
  – three types of diverging strategies

• Truck drivers do not fully utilize the available ramp and weaving segment length
  – Contribute more to the turbulence at the beginning

• The findings can be implemented in the existing microscopic simulation packages

• Design a control strategy to reduce the impact of lane changes (or turbulence) in the vicinity of motorway bottlenecks
Acknowledgements
Thank you!

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