Active Traffic Management strategies at expressway merging sections – A driving simulator study from Qatar

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Focus

1) Merging maneuvers of vehicles from short on-ramps: How does it affect driving performance and safety of outer lane expressway drivers?

2) Which traffic management strategies are effective to improve safety at these expressway merging sections?
Problem definition

Factors influencing driving behaviour at merging sections:

- Geometric configuration of the entrance ramp (~ 150 m)
- Speed differentials between merging and mainline vehicles
- Increased traffic density → conflicts with surrounding vehicles
Problem definition

- Traditional ramp metering does not take into account specific interaction between merging vehicle and outer-lane expressway driver

- Driver’s responses to merging vehicle:
  - Harsh deceleration and breaking
  - Abrupt lane change maneuvers

- Increased risks:
  - Traffic conflicts and turbulence
  - Higher likelihood of rear-end and sideswipe crashes
  - Congestion formation and bottlenecks
Research Question: Are ATM or PTM strategies more effective in preparing expressway drivers to safely respond to merging on-ramp vehicles?

Traffic Management Solutions

- Passive Traffic Management (PTM)
  - Merge warning signs (available in Qatar)
  - Road marking treatment

- Active Traffic Management (ATM)
  - Variable Message Signs (VMS)
    - e.g. dynamic lane control arrows
  - Variable Speed Limits (VSL)
Method

**Driving simulator at QTTSC – Qatar University**

- 135 degrees – horizontal field view
- Resolution: 5760 x 1080 pixels
- 60 HZ refresh rate
- Software: STISIM Drive® 3

- Data collection period: May 2018
- No compensation offered

- Pre-quiz: traffic control signs/ road markings
- Familiarization drive with simulator
- 2 experimental test drives of each 16 km
- Counterbalanced order of scenarios
Experimental test drives

Doha Rural Expressway

Replicated

Real-world view

Driving simulator view

Doha Urban Expressway

Replicated

Real-world view

Driving simulator view

Driving direction 1: urban (80 km/h) to rural (100 km/h) transition
Driving direction 2: rural (100 km/h) to urban (80 km/h) transition
Driving Scenarios: PTM

1. Control Scenario
2. Road marking

- Typical road configuration for expressways in Qatar
- Merge warning signs installed at expressway AND on-ramp
Driving Scenarios: PTM

1. Control Scenario

2. Road marking

RURAL & URBAN
Driving Scenarios: ATM

1. Merge control VMS
2. Combined VSL 80
3. Separated VSL 80

URBAN
Driving Scenarios: **ATM**

1. **Merge control VMS**
   - **150m**
   - **0m**
   - **-100m**
   - **-200m**
   - **-400m**

2. **Combined VSL 80**

3. **Separated VSL 80**

**RURAL**

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**DRIVING SCENARIOS**
Driving Scenarios: ATM

1. Merge control VMS

2. Combined VSL 80

3. Separated VSL 80

RURAL
Sample characteristics

- Subjects participated
  - Total: 72 (with Qatari driving license)
  - Male: 43 / Female: 29
  - 29 different nationalities
  - Mean age: 28.9 years

A) Origin of 66 participants:

- Qatari: 8%
- None Arab: 51%
- Other Arab: 41%

B) Registered active Driving Licenses in Qatar in 2016:

- Qatari: 7%
- None Arab: 70%
- Other Arab: 23%

Figure A+B: Proportion of drivers’ origin in this study vs. registered drivers in the State of Qatar (Ministry of Interior, Police Department, 2017)
Results: Mean speeds

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mean</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Rural: Control</td>
<td>96.4</td>
<td>14.5</td>
</tr>
<tr>
<td>Rural: Road marking</td>
<td>94.5</td>
<td>20.2</td>
</tr>
<tr>
<td>Rural: VMS lane specific</td>
<td>89.1</td>
<td>14.2</td>
</tr>
<tr>
<td>Rural: VMS general</td>
<td>89.9</td>
<td>16.8</td>
</tr>
<tr>
<td>Urban: Control</td>
<td>83.7</td>
<td>18.1</td>
</tr>
<tr>
<td>Urban: Road marking</td>
<td>78.6</td>
<td>14.7</td>
</tr>
<tr>
<td>Urban: VMS</td>
<td>82.5</td>
<td>16.7</td>
</tr>
</tbody>
</table>
Results: Mean Longitudinal Acc/Dec

Strong deceleration peak in the road marking condition on both expressways!

Deceleration peak in the rural expressway control condition.
Results: Mean Lateral Position

Early lane change initiation for VMS conditions on both expressways

Abrupt lane change in road marking condition on rural expressway!
Results: SD Lateral Acc/Dec

Homogenous lateral acceleration for control & VMS conditions

Peak variations in lateral acceleration for road marking condition on rural expressway
Conclusion: Urban Expressway

- No significant different longitudinal driving behaviors among ATM and PTM

- Earlier lane change maneuver when ATM is implemented → unnecessary road capacity reduction?

- Costly ATM have no additional safety benefits as compared to low cost PTM for urban expressway merge sections with a speed limit of 80 km/h
Conclusion: Rural expressway

- Significant safety effects due to ATM:
  - Number of safe lane changes increased by 35% as compared to PTM
  - Abrupt lane changes of through lane drivers were eliminated
  - Gradual and smooth mean speed reduction was achieved

- ATM prepared drivers to safely respond to merging vehicles, which increased traffic safety at merge sections of rural expressways (100 km/h)
Recommendation rural expressway:

- ATM strategies with VSL 80 km/h are recommended!
- Road marking treatment is **not** recommended for rural expressways (100 km/h)
Thank you for your attention!

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