Safety aspects of centrally situated bus public transport routes

Shalom Hakkert
Victoria Gitelman

Introduction

Literature findings

Analysis of central Public Transport Routes (PTR) and pedestrian crossing configurations (study 1)

Comparison of safety levels of various bus systems configurations: central PTR versus other types of bus-lanes (study 2)

SPIs: the concept (III)

Layout of presentation


Main findings: Overall safety impact of a BRT: Macrobús, Guadalajara

Main findings: Overall safety impact of a BRT: TransMilenio, Av. Caracas, TransMilenio


Main findings: Initial increase in fatalities after the implementation of the bus system

BRTs, BRT

Initially, increase in fatalities after the implementation of the bus system
Literature findings: safety impact of bus priority systems

<table>
<thead>
<tr>
<th>Change in Bus Speed</th>
<th>Crash</th>
<th>Injury</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in bus lane</td>
<td>-3%</td>
<td>-1%</td>
<td>-1%</td>
</tr>
<tr>
<td>Decrease in bus lane</td>
<td>-1%</td>
<td>-2%</td>
<td>-1%</td>
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<table>
<thead>
<tr>
<th>Change in Traffic Flow</th>
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<th>Death</th>
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<tbody>
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<td>-1%</td>
<td>-1%</td>
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<tr>
<td>Decrease in traffic speed</td>
<td>-1%</td>
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Literature findings: safety impact of common infrastructure changes associated with implementing bus priority systems

<table>
<thead>
<tr>
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<tr>
<td>Decrease in road surface</td>
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<table>
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<th>Death</th>
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<td>-1%</td>
</tr>
<tr>
<td>Decrease in traffic volume</td>
<td>-1%</td>
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Literature findings: Results of safety impact assessment on bus priority systems

<table>
<thead>
<tr>
<th>City</th>
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<th>Crash</th>
<th>Injury</th>
<th>Death</th>
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<tr>
<td>Mexico City</td>
<td>1%</td>
<td>-2%</td>
<td>-1%</td>
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</tr>
<tr>
<td>Gothenburg</td>
<td>2%</td>
<td>-1%</td>
<td>-1%</td>
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<tr>
<td>Bogotá</td>
<td>4%</td>
<td>-2%</td>
<td>-1%</td>
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</tr>
<tr>
<td>Melbourne</td>
<td>1%</td>
<td>-2%</td>
<td>-1%</td>
<td></td>
</tr>
</tbody>
</table>

Literature findings

- The safest place to be on a bus corridor is inside the bus
- The most dangerous: walking to the bus station

Literature findings

Factors influencing crash frequencies on bus corridors

- Speed

Speeding was the most common contributing factor listed in police crash reports for the Metrobus system in Mexico City.
Study 1: Analysis of central Public Transport Routes (PTR) and pedestrian crossing configurations

Characteristics of PTR studied:
- Central PTR, including left-side bus lane with stops on median
- Main arterials with heavy traffic and pedestrian activity
- At least two traffic lanes per direction
- A PTR lane in each direction
- Signalised 3- and 4-legged intersections

The problem:
- Many crashes with pedestrians at intersections on PTR
- Source of problem:
  - Unfamiliar situation for crossing pedestrians:
  - Having to cross three traffic streams in opposing directions
  - Long waiting times for crossing pedestrians
  - The PTR is bi-directional with relatively little traffic
Study 1: Pedestrian crossing configurations at signalized intersections with central PTR

- Type 1 – a direct three-routes crossing
- Type 2 – a gradated right-right crossing
- Type 3 – a gradated left-left crossing
- Type 4 – a gradated-crossing with mixed-shifting: right-left or left-right
- Type 5 – a direct two-routes crossing

Study 1: Examples of pedestrian crossings at signalized intersections with central PTR, in Israel

- Type 1: Rothschild boulevard, in Haifa
- Type 2: Haatzmaut road, in Haifa
- Type 3: Jabotinsky road, in Petah Tiqwa
- Type 4: Balfour street, in Bat-Yam
- Type 5: Haatzmaut road, in Haifa

Study 1: Analysis of central PTR and pedestrian crossing configurations

Type of analyses:
1. Safety indices for various intersection configurations
2. Comparison of crash indices for intersections by:
   a. Type of crossing configuration
   b. Number of intersection legs
   c. Comparison of indices with comparison sites

Study 1 findings: Characteristics affecting the number of accidents at the study sited

- Crossing type 3 gradated left-left had a consistent negative correlation with accidents
- Crossing type 4 gradated right-right had a consistent positive correlation with accidents

Regression models:
- For all types of crashes – Crossing type 4 is associated with an increase in accidents

Non-parametric comparison of average no. of accidents:
- Differences between type 4 and type 3 crossings is significant and, in some cases, between type 3 and type 1 (straight across – is better than type 4 but worse than type 3)
Study 1: Comparing accident indices* at the PTR sites, by junction configuration

<table>
<thead>
<tr>
<th>Sites groups</th>
<th>All accidents</th>
<th></th>
<th></th>
<th></th>
<th>Pedestrian accidents</th>
<th></th>
<th></th>
<th></th>
<th>Accidents involving buses</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Serious</td>
<td>Fatal</td>
<td>Total</td>
<td>Serious</td>
<td>Fatal</td>
<td>Total</td>
<td>Serious</td>
<td>Fatal</td>
<td>Average accident indices:</td>
<td>3-legged 5.7 0.6 0.2 1.5 0.4 0.1 1.3 0.2 0.1</td>
<td>4-legged 8.2 0.9 0.4 1.9 0.5 0.3 1.8 0.4 0.4</td>
</tr>
</tbody>
</table>

* Significant difference * in 2010-2012

Study 1: Comparing accident indices* at the PTR sites and comparison-group (CG) sites, by junction configuration

<table>
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<th></th>
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<th></th>
<th>Accidents involving buses</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PTR junctions</td>
<td>5.7*</td>
<td>0.6</td>
<td>0.2</td>
<td>1.5</td>
<td>0.4</td>
<td>0.1</td>
<td>1.3</td>
<td>0.2</td>
<td>0.1</td>
<td>4-legged 8.2 0.9 0.4 1.9 0.5 0.3 1.8 0.4 0.4</td>
<td>Differences between the site groups, estimated by means of T-statistics (p-values):</td>
<td>3-legged vs 4-legged 0.007* 0.281 0.162 0.400 0.627 0.216 0.264 0.251 0.054*</td>
</tr>
</tbody>
</table>

* Significant difference * in 2010-2012

Study 1: Main conclusions

- Crossing type 4 gradated right-left, was consistently found to perform worst, type 3 gradated left-left - to perform best. In addition, the accident analysis results provide an indication that a direct crossing (type 1 and type 5) is safer than a mixed shifting (type 4).
- Pedestrian crossing configurations of types 1, 3 and 5 are recommended.
- Behaviour observations at PTR junctions: a significant proportion of pedestrians cross on red: 7-27%. It is important to create consecutive green phases for the pedestrians to minimize waiting times.

Type 1

Type 3

Study 2: Comparison of safety level of central PTR with other types of bus lanes

Typical bus-lane layouts:
- Central PTR
- Right (curb-side) bus lane
- Left side bus-lane

Problem: a central PTR on Jabotinsky road, in Petah Tiqwa, experienced a lot of pedestrian accidents at intersections

Study aims:
(1) To compare the safety level of Jabotinsky road with that of similar streets
(2) To compare the safety level of central PTR with those of other bus-lane configurations

Study 2: safety level of Jabotinsky road with central PTR vs. similar streets with public transport

Main findings:
- Arterials with intensive public transport have intensive land-use, vehicle and pedestrian activities. They generally have accident concentrations.
- Jabotinsky road appears in the list of such streets but is not among the worst.

Data:
- 26 arterials with bus-lanes, in 9 towns
- Data on traffic volumes were collected
- Crash data for years 2010 – 2013
- 137 intersections and 92 road segments
### Study 2: Street characteristics examined

- **Central PTR vs right bus-lane**
- **Central PTR vs left bus-lane**
- **Central PTR vs right bus-lane**

#### Type of bus-lane layout
- (central PTR, right-side, left-side)
- **Number of traffic lanes in each direction**
- **Level of pedestrian activity** (low, high)
- **Traffic volumes entering intersection in 14 hours**
- **Numbers of buses on the main roads**
- **Type of area** (urban, interurban)

#### Accident rates
- **Bus-lane type**
- **Left bus-lane**
- **Right bus-lane**
- **Central PTR**

### Differences between the site groups

- **All injury accidents**
- **Serious and fatal accidents**
- **Accidents with pedestrian and buses**
- **Accidents with bus involvement**

### Study 2: Methods of analysis

#### A. Comparison of accident indices by PTR type:
- **annual number of accidents and accident rates per exposure (10 million vehicles per year, 1 million passing buses) or per section length**

\[ T = \ln(y) / \sqrt{(N_1 + N_2)/2} \]

where: \( \theta = R_1 / R_2 \)
- **N1** - total number of accidents per study group
- **N2** - total number of accidents per comparison group
- **R1** - accident index in study group
- **R2** - accident index in comparison group
- Ho: \( \theta = 1 \), rejected when \( p<0.05 \)

#### B. Fitting explanatory models to predict the number of accidents at intersections/sections, using available characteristics

- **Multivariate Analysis of Variance (MANOVA) in SPSS v.22**

### Study 2: Junctions - comparing accident indices by PTR type

#### Accident rates per 10 million entering vehicles, per junction, per year

- **Central PTR vs right bus-lane**
- **Central PTR vs left bus-lane**
- **Central PTR vs right bus-lane**

#### Differences between the site groups

- **Accident rates per 10 million passing busses, per junction, per year**

#### Types of accidents analysed:
- All injury accidents
- Serious and fatal accidents
- Pedestrian accidents
- Accidents with bus involvement
- Accidents with pedestrian and buses

### Study 2: Junctions - comparing accident indices by PTR type

#### Accident rates per 1 million passing busses, per junction, per year

- **Central PTR vs right bus-lane**
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- **Central PTR vs right bus-lane**

#### Differences between the site groups

- **Accident rates per 1 million passing busses, per section length**

### Study 2: Explanatory models for accidents at junctions

#### Methods of analysis

- **Safety Studies, Institute of Transportation Engineers**

### Study 2: Average accident numbers per junction, per year

- **Central PTR vs right bus-lane**
- **Central PTR vs left bus-lane**
- **Central PTR vs right bus-lane**

### Differences between the site groups

- **Central PTR vs right bus-lane**
- **Central PTR vs left bus-lane**

### Study 2: Explanatory models for accidents at junctions

#### Total accidents

- **Central PTR vs central PTR**
- **Central PTR vs right bus-lane**
- **Central PTR vs left bus-lane**
- **Traffic volume on secondary road**
- **Type of area** (urban, interurban)
- **Type of bus-lane layout**

### Pedestrians accidents

- **Central PTR vs central PTR**
- **Central PTR vs right bus-lane**
- **Central PTR vs left bus-lane**
- **Traffic volume on secondary road**
- **Type of area** (urban, interurban)
- **Level of pedestrian activity** (low, high)

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<td>0.04</td>
<td>0.35</td>
<td>0.15</td>
<td>0.39</td>
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<tr>
<td></td>
<td>SD</td>
<td>0.05</td>
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<td>0.16</td>
<td>0.27</td>
<td></td>
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<td></td>
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<td>0.05</td>
<td>0.03</td>
<td></td>
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</tbody>
</table>
Study 2: Explanatory models for accidents at junctions – main findings

- Right- and left-bus-lane configurations are associated with accident decrease compared to central PTR, in all accident types
- Increase in the number of buses leads to an increase in total, bus and bus-pedestrian accidents
- Higher pedestrian activity is associated with a decrease in pedestrian, bus and bus-pedestrian accidents
- PTR overtaking lane is associated with an increase in bus and bus-pedestrian accidents
- Interurban area decreases the number of pedestrian accidents
- Higher traffic volumes on secondary road increases the number of total and severe accidents
- The impact of traffic volumes on the main roads, number of lanes not significant

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<tr>
<td>SD</td>
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<td>1.82</td>
<td>0.76</td>
<td>0.76</td>
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</tr>
</tbody>
</table>

Differences between the site groups

- Central PTR vs right bus-lane
  - T-value: 0.09
  - p-value: 0.18
- Central PTR vs left bus-lane
  - T-value: 0.07
  - p-value: 0.18

Study 2: Sections - comparing accident indices by PTR type

- Average accident numbers per road km, per year

<table>
<thead>
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<th>Bus-lane type</th>
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<td>0.06</td>
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<td>SD</td>
<td>0.23</td>
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<td>Mean</td>
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<td>Mean</td>
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<td>0.32</td>
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<tr>
<td>SD</td>
<td>1.53</td>
<td>0.73</td>
<td>0.51</td>
<td>0.34</td>
<td>0.34</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Differences between the site groups

- Central PTR vs right bus-lane
  - T-value: 2.58
  - p-value: 0.01
- Central PTR vs left bus-lane
  - T-value: 1.93
  - p-value: 0.05

Study 2: Safety level of central PTR vs. other bus-lane configurations – Conclusions

- Intersections situated on central PTR have a lower safety level compared with other bus-lane configurations
- Much attention has to be given to the detailed design features at PTR intersections, with particular emphasis on pedestrian arrangements
- Road sections of central PTR have a higher level of safety compared with other bus-lane configurations, mainly due to the extensive presence of median barriers/fencing

Final remarks

- Main questions remain with regard to particular design features of PTR intersections, bus stops, pedestrian settings and their impacts on road safety
- More research efforts are required to ascertain safety effects
- Main focus on pedestrian safety
- Behaviour studies may supply initial insights
- More simple engineering solutions are preferable
- Remember to keep a balance between promoting public transport use and pedestrian safety

Thank you!