Road traffic safety analysis at U-turns on Thai highways using Traffic Conflict Technique

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Road traffic safety: socio-economics costs

- Approximately 1.24 million people were killed on the world’s roads in 2010 and another 20 to 50 million sustain nonfatal injuries as a result of road traffic crashes (WHO 2013).

- The negative consequences from road accidents are regarded as socio-economic costs.

- Road Traffic accident socio-economic (losses) costing for Thailand:
  - Approx. 2.56 percent of the GDP in 2002 (Luathep and Yordphol 2005)
  - Approx. 2.37 percent of the GDP in 2004 (Thongchim, et al. 2007)
  - Approx. 3 percent of the GDP in 2010 (WHO 2013)


Introduction

Need of study: Contributing Crash Factors

![Diagram showing the distribution of contributing factors in road accidents.]

Objective of study

Road safety analysis of U-turns on Thai Highways with focus on their geometric design.

• Layout Geometric of the U-turns...
• Accident based safety analysis: accident cost rate...
• Assessment of accident database...
• Event/conflict based safety analysis: TCT...
• Assessment of ‘conflict index rate’...
• Affect of variation of U-turn variables...
• Most safest layout design...

Introduction

Need of study: Crashes at U-turns

Reported road traffic fatalities (2010) 13766 and estimated GDP lost due to road traffic crashes about 3 percent (Source: WHO, Global status report on road safety 2013).
U-turn on Thai Highways

- to facilitate road user to change to opposite traffic stream,
- to avoid construction of T-junctions,
- to reduce travel time for emergency services,
- for efficient law enforcement, and
- for highway maintenance purposes.

Distance between two adjacent U-turns are varying from approx. 1.5 to 3 km, depends upon field geography.

Combination of U-turn equivalent to 4-legged intersection

- Nos. of conflict points
- Conflict types
- Speed
- Access controls
- Density (facility per km) on highways

32 Conflict points
12 Conflict points
Scope of study

...focus on crash and conflict based investigation methods.
...limited to U-turns on rural 4-lane divided highways (DoH).

Limitations for selection of U-turns locations:
• Outside of built-up area,
• Highway having median width 0.5m to 15m,
• Not to be located on horizontal curve,
• Not to be located on crest,
• Not to be part of T or X-junction,
• Not to be grade separated design, and
• No special design solution.

Accident data source:
• Royal Thai Police
• Department of Highway

Classification of U-turns
Classification of U-turn types

Based on layout geometric design, 8 types of U-turn classified for study:

- **UT-1**
- **UT-2**
- **UT-3**
- **UT-4**
Classification of U-turn types

Based on layout geometric design, 8 types of U-turn classified for study:

- UT-5
- UT-6
- UT-7
- UT-8

Safety analysis approaches

Road safety analysis

- Accident based analysis
  - Advantages
  - Disadvantages
- Conflict based analysis
  - Advantages
  - Disadvantages

...
Advantage and disadvantages of accident based analysis

Road safety analysis

Accident based analysis

Advantages
- Widely accepted
- Highly reliable

Disadvantages
- Available and reliable accident data
- Longer time period (1 – 3 year)

Advantage and disadvantages of event based analysis

Road safety analysis

Conflict based analysis

Advantages
- Accepted as surrogate approach
- Shorter time duration

Disadvantages
- Depends upon subjective (observer’s) decisions
Road safety analysis

Accident based analysis

Data requirements
- Accident data
  - Accident type
  - Accident category
- Traffic data
  - Volume (AADT)

Conflict based analysis

Data requirements
- Conflicting data
  - Conflict types
  - Conflict severity
- Traffic data
  - Volume
  - Vehicle composition

Data requirement

Road safety analysis

Accident based analysis

Data requirements
- Accident data
  - Accident type
  - Accident category
- Traffic data
  - Volume (AADT)

Data sources
1. Royal Thai Police
2. Department of Highways (DoH)

Assessment of availability and reliability of accident data (Pilot Study)
Some facts about accident data in Thailand (Srirat 2008):

- DOH has a trend of underreporting in the night time,
- DOH has more underreporting trend during weekend than during weekdays,
- The accident involving the crash between vehicle and object are always under-reported by police but in other cases DOH has a trend of underreporting,
- The small vehicles crashes have more tendencies to be under-reported by DOH than police, and
- The hospital data collect the case of severity, disability and death, but not providing the property damage.

Figure: Road traffic accident under-reporting between DoH and Royal Thai Police (Nakhon Ratchasima province)  
Source: Srirat 2008
The objective evidence of a traffic conflict by the definition is the evasive action which is indicated by a brake-light or a lane change affected by the offended driver.

Traffic Conflict Techniques: have been advocated as a proactive and supplementary approach to collision-based road safety analysis.

Traffic conflict: an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged.

The basic hypothesis is that there is a close relationship between conflicts and accidents.

A major advantage of using traffic conflicts over traffic collisions in safety studies is the significant shorter observation period required; data can be collected over a matter of days or weeks with conflicts as opposed to years using collision records.
Conflicts based analysis

Data requirement

Road safety analysis

Conflict based analysis

Objective

Subjective

Conflict measure
• TA/Speed
• TTC
• PET
•...

Conflict measure
• Evasive action

Requirements
• Require sophisticated positions of video camera for recording
• Image processing computer programs

Requirements
• Require trained technical observers.
Conflicts based analysis

Data requirement

Road safety analysis

Conflict based analysis

Data requirements
- Conflicting data
- Conflict types
- Conflict Severity/Intensity

Traffic data
- Volume
- Composition

Field Data collection

Traffic Conflict Technique

U-turn zones

Downstream Zones

Turning Zone

Upstream Zones

Source: Own draft
Traffic Conflict Technique

Conflicts points at U-turn

UT-1: A total 13 conflicts points

UT-2: A total 13 conflicts points

UT-3: Total 13 conflicts points

UT-4: Total 12 conflicts points
UT-6: Total 17 conflicts points

Traffic Conflict Technique

Conflicts points at U-turn

Diverging
Merging
Crossing
Head-on

UT-5: Total 17 conflicts points

UT-8: Total 17 conflicts points

UT-7: Total 17 conflicts points
Traffic Conflict Technique (Indicators)

Conflict severity parameters (subjective approach)

1) Slight traffic conflict:
   
   Sudden lane change or mere braking

2) Moderate traffic conflict:
   
   Intense decelerate vehicle and almost stop

3) Severe traffic conflict:
   
   Hard braking or skid marks or braking sound
Traffic Conflict Technique

Conflict point grouping

Upstream Zone
- UD: Diverging
- UC: Crossing

Turning Zone
- TH: Head-on

Turning Zone
- DM: Merging
- DC: Crossing

Downstream Zone

- **Merging**
  - DM1: Slight Conflict
  - DM2: Moderate Conflict
  - DM3: Sever Conflict

- **Crossing**
  - DC1: Slight Conflict
  - DC2: Moderate Conflict
  - DC3: Sever Conflict

- **Secondary**
  - DS1: Slight Conflict
  - DS2: Moderate Conflict
  - DS3: Sever Conflict

Upstream Zone

- **Head-on**
  - TH1: Slight Conflict
  - TH2: Moderate Conflict
  - TH3: Sever Conflict

- **Secondary**
  - TS1: Slight Conflict
  - TS2: Moderate Conflict
  - TS3: Sever Conflict
## Field data collection: Locations of identified U-turns

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Type</th>
<th>Province</th>
<th>Distance from HDY</th>
<th>Data collection status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UT-1</td>
<td>Sadao, Songkla</td>
<td>45Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>2</td>
<td>Ratchaburi</td>
<td></td>
<td>880Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>3</td>
<td>UT-2</td>
<td>Songkla</td>
<td>17Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>4</td>
<td>Songkla</td>
<td></td>
<td>20Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>5</td>
<td>UT-3</td>
<td>Chai Nat</td>
<td>1122Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>6</td>
<td>Nakhon Si Ayutthaya</td>
<td></td>
<td>994Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>7</td>
<td>UT-4</td>
<td>Nakhon Si Thammarat</td>
<td>195Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>8</td>
<td>Nakhon Si Thammarat</td>
<td></td>
<td>193Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>9</td>
<td>UT-5</td>
<td>Phatthalung</td>
<td>117Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>10</td>
<td>Phatthalung</td>
<td></td>
<td>105Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>11</td>
<td>UT-6</td>
<td>Songkla</td>
<td>140Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>12</td>
<td>Songkla</td>
<td></td>
<td>130Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>13</td>
<td>UT-7</td>
<td>Phatthalung</td>
<td>96Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>14</td>
<td>Phatthalung</td>
<td></td>
<td>100Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>15</td>
<td>UT-8</td>
<td>Phetchaburi</td>
<td>1254Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td>16</td>
<td>Phetchaburi</td>
<td></td>
<td>1212Km</td>
<td>8 Hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>128 Hours</strong></td>
</tr>
</tbody>
</table>

### Data collection

**Criteria for field data collection**

- Two of each type of U-turn were considered for data collection (total 16 U-turns)
- Total 8 hours of data collection planned for each location
  - 2 peak hours for each side (total 4 hours for each U-turn)
  - 2 off peak hours for each side (total 4 hours for each U-turn)
  - Only in day-light hours
  - No adverse weather condition (heavy rain, thunder shower etc)
  - No weekend or holidays
Field Data collection

Outcome of field study

1) Conflicts at Turning zone: Very rare.
2) Severe traffic conflict: Only one incidence was recorded.

Geometric Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_m$</td>
<td>Median width</td>
</tr>
<tr>
<td>$W_{am}$</td>
<td>Median width along auxiliary lane</td>
</tr>
<tr>
<td>$W_t$</td>
<td>Through lane width</td>
</tr>
<tr>
<td>$W_{dc}$</td>
<td>Width of deceleration lane</td>
</tr>
<tr>
<td>$W_{ac}$</td>
<td>Width of acceleration lane</td>
</tr>
<tr>
<td>$W_{ow}$</td>
<td>Width of outer widening</td>
</tr>
<tr>
<td>$W_{os}$</td>
<td>Width of outer shoulder</td>
</tr>
<tr>
<td>$W_{is}$</td>
<td>Width of inner shoulder</td>
</tr>
<tr>
<td>$L_{mo}$</td>
<td>Length of median opening</td>
</tr>
<tr>
<td>$L_{dc}$</td>
<td>Length of deceleration lane</td>
</tr>
<tr>
<td>$L_{ac}$</td>
<td>Taper section length of deceleration lane</td>
</tr>
<tr>
<td>$L_{at}$</td>
<td>Length of acceleration lane</td>
</tr>
<tr>
<td>$L_{aw}$</td>
<td>Taper section length of acceleration lane</td>
</tr>
<tr>
<td>$L_{ow}$</td>
<td>Length of outer widening</td>
</tr>
<tr>
<td>$L_{os}$</td>
<td>Upstream taper section length of outer widening</td>
</tr>
<tr>
<td>$L_{is}$</td>
<td>Downstream taper section length of outer widening</td>
</tr>
</tbody>
</table>
**Geometric Data**

**Functional length of Auxiliary lanes**

- $L_{dc}$ – Length of the section of deceleration lane with full width,
- $L_{dt}$ – Length of the taper section of the deceleration,
- $L_{df}$ – Functional length of the deceleration lane $= L_{dc} + L_{dt}/2$
- $L_{ac}$ – Length of the section of acceleration lane with full width,
- $L_{at}$ – Length of the taper section of the acceleration,
- $L_{af}$ – Functional length of the acceleration lane $= L_{ac} + L_{at}/2$

<table>
<thead>
<tr>
<th>U-turn type</th>
<th>$L_{dc}$ [m]</th>
<th>$L_{dt}$ [m]</th>
<th>$L_{df}$ [m]</th>
<th>$L_{ac}$ [m]</th>
<th>$L_{at}$ [m]</th>
<th>$L_{af}$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UT-2</td>
<td>32</td>
<td>46</td>
<td>56</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UT-3</td>
<td>105</td>
<td>68</td>
<td>139</td>
<td>148</td>
<td>61</td>
<td>177</td>
</tr>
<tr>
<td>UT-4</td>
<td>99</td>
<td>52</td>
<td>124</td>
<td>99</td>
<td>50</td>
<td>124</td>
</tr>
<tr>
<td>UT-5</td>
<td>68</td>
<td>58</td>
<td>97</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UT-6</td>
<td>62</td>
<td>88</td>
<td>106</td>
<td>62</td>
<td>92</td>
<td>108</td>
</tr>
<tr>
<td>UT-7</td>
<td>61</td>
<td>131</td>
<td>127</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UT-8</td>
<td>100</td>
<td>59</td>
<td>129</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Variety! Consistency! Uniformity!

**Traffic Conflict Technique**

**Traffic volumes at U-turns**

- $HThV$ – Hourly through volume,
- $HDIV$ – Hourly diverging volume,
- $HMeV$ – Hourly merging volume,
Traffic Data

Traffic streams and composition

- Through traffic
- Diverging
  - Using deceleration lane
  - Not-using deceleration lane
- Merging
  - Using acceleration lane
  - Not-using acceleration lane

Traffic composition

<table>
<thead>
<tr>
<th>Motorbike</th>
<th>Passenger Car</th>
<th>Bus/ Truck Up to 10 wheels</th>
<th>Tractor-Trailer &gt; 10 wheels</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>🏷️</td>
<td>🚗</td>
<td>🚌</td>
<td>🌞</td>
<td>🏷️</td>
</tr>
</tbody>
</table>

Data collection

Observed traffic volumes at U-turns
Methodology

Exposure

“the total number of traffic conflicts is proportional to the square root of the product of the conflicting volumes”  

\[ PEV = \sqrt{(V_1 \times V_2)} \]

where:

\( V_1 \) and \( V_2 \) represent the traffic volumes (veh/hr) of the two conflicting traffic streams.

U-turn: Product of through and turning volumes (PTTV\textsuperscript{top}, PTTV\textsuperscript{bot}, & PTTV)

“the square root of the product of (average hourly) traffic volumes of the conflicting streams (through and turning)”.

Methodology

Conflict numbers:

Hourly Traffic Conflict Number (HCN):

defined as the number of observed conflicts at a zone divided by the number of observation hours for that zone.

Average Hourly Traffic Conflict Number (AHN):

defined as the summation of Hourly Traffic Conflict Numbers (HCN) at that particular zones divided by the number of that type of zones in particular group of U-turn type.
Methodology

Coefficient of Conflict Severity (CCS):
(From a study of roundabouts...)

<table>
<thead>
<tr>
<th>Conflict seriousness</th>
<th>Coefficient of Conflict Severity (Weighting factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight Conflict</td>
<td>1</td>
</tr>
<tr>
<td>Moderate Conflict</td>
<td>3</td>
</tr>
<tr>
<td>Serious Conflict</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: Krivda (2013)

<table>
<thead>
<tr>
<th>Road segment</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round-about</td>
<td>40km/h (Design speed, rural area)</td>
</tr>
<tr>
<td>U-turns</td>
<td>75 to 90 km/h (Average speed)</td>
</tr>
</tbody>
</table>

2 – Observed average speed at U-turns for cars

Weighted conflict rate:
(From a study of roundabouts...)

\[
C_{GW} = \frac{\sum_{i=1}^{n} N_{CS1} \times C_{SF} \times 100}{V}
\]

where:
\(C_{GW}\) - weighted conflict rate [CS/100 veh],
\(N_{CS}\) - number of conflict situations [CS/h],
\(C_{SF}\) - coefficient of seriousness of conflict situations [-],
\(i\) - number of conflict situations of the same type \(i = 1, 2, 3\),
\(j\) - seriousness of conflict situations \(j = 1, 3\),
\(C_{SF1}\) - for seriousness of conflict situations of the 1st level,
\(C_{SF3}\) - for seriousness of conflict situations of the 3rd level,
\(V\) - Hourly traffic volume [veh/h],

Source: Krivda (2013)
Severity conflict index rate:

...for Downstream zones

\[
SCI_{\text{dn}} = \frac{\text{AHN}_{\text{dn}-\text{sl}} \times \text{CSS}_{\text{sl}} + \text{AHN}_{\text{dn}-\text{md}} \times \text{CSS}_{\text{md}} + \text{AHN}_{\text{dn}-\text{sv}} \times \text{CSS}_{\text{sv}}}{\text{PTTV}_{\text{dn}}}
\]

where:
- \(SCI_{\text{dn}}\) = Severity Conflict Index for Downstream Zones,
- \(\text{CSS}_{\text{sl}}\) = Coefficient of seriousness of slight conflict = 1,
- \(\text{CSS}_{\text{md}}\) = Coefficient of seriousness of moderate conflict = 3,
- \(\text{CSS}_{\text{sv}}\) = Coefficient of seriousness of severe conflict = 6,
- \(\text{AHN}_{\text{dn}-\text{sl}}\) = Average Hourly Slight Traffic Conflict Number for Downstream Zones,
- \(\text{AHN}_{\text{dn}-\text{md}}\) = Average Hourly Moderate Traffic Conflict Number for Downstream Zones,
- \(\text{AHN}_{\text{dn}-\text{sv}}\) = Average Hourly Severe Traffic Conflict Number for Downstream Zones,
- \(\text{PTTV}_{\text{dn}}\) = Product of through and turning volumes for Downstream Zones

Severity conflict index rate:

...for Upstream zones

\[
SCI_{\text{up}} = \frac{\text{AHN}_{\text{up}-\text{sl}} \times \text{CSS}_{\text{sl}} + \text{AHN}_{\text{up}-\text{md}} \times \text{CSS}_{\text{md}} + \text{AHN}_{\text{up}-\text{sv}} \times \text{CSS}_{\text{sv}}}{\text{PTTV}_{\text{up}}}
\]

where:
- \(SCI_{\text{up}}\) = Severity Conflict Index for Upstream Zones,
- \(\text{CSS}_{\text{sl}}\) = Coefficient of seriousness of slight conflict = 1,
- \(\text{CSS}_{\text{md}}\) = Coefficient of seriousness of moderate conflict = 3,
- \(\text{CSS}_{\text{sv}}\) = Coefficient of seriousness of severe conflict = 6,
- \(\text{AHN}_{\text{up}-\text{sl}}\) = Average Hourly Slight Traffic Conflict Numbers for Upstream Zones,
- \(\text{AHN}_{\text{up}-\text{md}}\) = Average Hourly Moderate Traffic Conflict Numbers for Upstream Zones,
- \(\text{AHN}_{\text{up}-\text{sv}}\) = Average Hourly Severe Traffic Conflict Numbers for Upstream Zones,
- \(\text{PTTV}_{\text{up}}\) = Product of through and turning volumes for Upstream Zones
Severity conflict index rate:

...for U-turns

\[
SCI = \frac{AHN_{sl} \times CSS_{sl} + AHN_{mod} \times CSS_{mod} + AHN_{sev} \times CSS_{sev}}{PTTV}
\]

where:

- \(SCI\) = Severity Conflict Index for a group of U-turn type,
- \(CSS_{sl}\) = Coefficient of seriousness of slight conflict = 1,
- \(CSS_{mod}\) = Coefficient of seriousness of moderate conflict = 3,
- \(CSS_{sev}\) = Coefficient of seriousness of severe conflict = 6,
- \(AHN_{sl}\) = Average Hourly Slight Traffic Conflict Numbers,
- \(AHN_{mod}\) = Average Hourly Moderate Traffic Conflict Numbers,
- \(AHN_{sev}\) = Average Hourly Severe Traffic Conflict Numbers,
- \(PTTV\) = Product of through and turning (merging & diverging) volumes

Results

Severity Conflict Indexes at Upstream Zones

[Diagram showing SCI values for different U-turn types (UT-1 to UT-8)]
Severity Conflict Indexes at Downstream zones

Severity Conflict Indexes for U-turns
Secondary results

Effect of the directional island

Other findings

Inappropriate driving behaviors
Inappropriate driving behaviors

Other findings
Illegal parking at U-turn

Thank you

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