Temporal and Spatial Impacts of Rainfall Intensity on Traffic Accidents in Hong Kong

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Population: ~ 7 million
Total area: 1104 km², about 20% land developed
Car ownership: 52 per 1000 people, about 10% of the US figure, despite a similar level of GDP
Urban density: 34,000 persons/km²
In comparison: Los Angeles - 3,144;
Taipei – 9,650; Tokyo - 7,100; Bangkok – 1.301

12 million daily trips, ~10% of car trips

- Road length = 2 076km
- No. of licensed vehicle = 613 000
- 60% of licensed vehicles are private cars
- The remaining 40% of them are commercial vehicles (including taxi, public light buses, goods vehicles, coaches and buses).
Background

Transportation network under adverse weather conditions in Hong Kong

13:04 26 May 2006 (Fri) - no rain
13:04 29 May 2006 (Mon) - raining
In Hong Kong, there are three levels of rainstorm warning: AMBER, RED and BLACK.


The AMBER rainstorm signal gives alert about potential heavy rain that may develop into RED or BLACK signal situations. There will be flooding in some low-lying and poorly drained areas.

The RED and BLACK rainstorm signals warn the public of heavy rain which is likely to bring about serious road flooding and traffic congestion. They will trigger response actions by Government departments and major transport and utility operators. The public will be given clear advice on the appropriate actions to take.

AMBER, RED and BLACK rainstorm signals: Heavy rain has fallen or is expected to fall generally over Hong Kong, exceeding 30, 50 and 70 millimetres in an hour respectively, and is likely to continue.
Adverse weather is a major environmental risk which would significantly affects traffic crash and casualty rates in urban areas.
In Hong Kong, rainfall is the major adverse weather with significant impacts on road safety.

- Low road friction
- Low visibility
Based on the rainfall data (annual averages for 30-year period) from the World Weather Information Services, Hong Kong has the highest average annual rainfall among other major Pacific Rim cities.
According to data from the Transport Department of Hong Kong, an average of 14.96% traffic accidents occurred under rainy conditions during 2005-2010 in Hong Kong.
It is important to investigate the relationship between rainfall and road accidents.

Some scholars have conducted empirical studies to investigate the impacts of adverse weather on road traffic accidents:

- Ivey et al., 1975
- Andrey et al., 2003
- Eisenberg, 2004
- Keay et al., 2006
- Andrey, 2010
- Mills et al., 2011
- etc.

Limitations?
LIMITATIONS

Spatial

Use rainfall data collected from one or limited number of weather stations to represent rainfall intensity over a large area.

Temporal

There is a need to explore the hourly variation of accident counts in association of the rainfall intensities.

Less representative rainfall intensity

Lack of hourly analysis
This Study

Spatial Analysis

Thiessen Polygon

Matched-pair

Representative Rainfall Intensity

Hourly impacts of Rainfall Intensity

Temporal Analysis
DATA

- 2009-2010 Rainfall Intensity Data (Provided by the Hong Kong Observatory)

- 2009-2010 Traffic Accident Data (Provided by the Transport Department of Hong Kong Government)
Spatial Analysis

Hong Kong territory is divided into a number of polygon regions.

With the use of the Thiessen-polygon approach, each weather station is surrounded by a polygon which is formed by the adjacent perpendicular bisectors.
Rainfall data collected from rainfall gauge station in each region has been used to represent the regional rainfall intensity.
Inverse distance-weighted approach is adopted to estimate rainfall intensity when traffic accident occurred at location nearby multiple rainfall gauge stations.

\[ R = \frac{\sum_{i=1}^{n} r_i \times \frac{1}{d_i}}{\sum_{i=1}^{n} \frac{1}{d_i}}. \]

Notations:
- **R**: estimated rainfall intensity at accident location
- **r_i**: hourly rainfall intensity collected from corresponding rainfall gauge station
- **d_i**: distance from accident location to rainfall gauge station
METHODOLOGY

Temporal Analysis

<table>
<thead>
<tr>
<th>Pre-event</th>
<th>Event</th>
<th>Post-Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-control</td>
<td>Control</td>
<td>Post-Control</td>
</tr>
</tbody>
</table>

This study defines six time periods for each matched-pair, i.e., pre-event, event, post-event, pre-control, control and post-control.

- **Event:** rainy conditions
- **Control:** Non-rainy conditions, the same time period of the event but one week apart (excluding public holidays)
METHODOLOGY

Temporal Analysis

Matched-pair periods

<table>
<thead>
<tr>
<th>Pre-event</th>
<th>Event</th>
<th>Post-event</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>-2</td>
<td>-1</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Pre-control</th>
<th>Control</th>
<th>Post-control</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>-2</td>
<td>-1</td>
</tr>
</tbody>
</table>

Notes: -1, -2, and -3: the first, second, and third hour before the rain
1, 2, and 3: the first, second, and third hour after the rain

Each of the Pre-event, Post-event, Pre-control and Post-control time periods is 3 hours, respectively. The Event and Control time periods are varied from one to 12 hours. In total, 436 matched-pair dataset were sorted for analysis.
TABLE 2 Average Number of Accidents for Matched Pairs

Temporal Analysis

<table>
<thead>
<tr>
<th></th>
<th>Pre-event</th>
<th>Event</th>
<th>Post-event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of accidents</td>
<td>0.1195</td>
<td><strong>0.7530</strong></td>
<td><strong>0.2360</strong></td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>0.0970</td>
<td>0.7022</td>
<td>0.2010</td>
</tr>
<tr>
<td>Upper</td>
<td><strong>0.1421</strong></td>
<td><strong>0.8038</strong></td>
<td><strong>0.2710</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Pre-control</th>
<th>Control</th>
<th>Post-control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of accidents</td>
<td>0.0467</td>
<td><strong>0.0859</strong></td>
<td><strong>0.0215</strong></td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>0.0322</td>
<td>0.0681</td>
<td>0.0137</td>
</tr>
<tr>
<td>Upper</td>
<td><strong>0.0612</strong></td>
<td><strong>0.1037</strong></td>
<td><strong>0.0292</strong></td>
</tr>
</tbody>
</table>

Under rainy conditions, the average hourly number of accidents increases rapidly to **0.7530** per hour which is much greater than that in the Control period in a similar environment but with no rain. When the rain stops, the road is still wet. During this period, the number of accidents falls to **0.2360** per hour, which is lower than that in the Event period but still higher than that in the corresponding post-control period (**0.0215** accidents per hour).
RESULTS AND DISCUSSION

Temporal Analysis

The first hour of rain and the first hour after rain are the accident-prone periods.
RESULTS AND DISCUSSION

Spatial Analysis

\[ RINC = \frac{C}{RH} \]

*RINC*: rainfall intensity-normalized count, i.e., frequency of traffic accidents per hour.
*C*: number of traffic accidents under certain rainfall intensity.
*RH*: total hours under certain rainfall intensity interval.

1. Increase in hourly counts of traffic accidents under rainfall intensity of 19 to 26 mm per hour is higher than that under other rainfall intensities.
2. Excessive rainfall results (> 26 mm/hour) in an increase in discomfort and difficulty in driving, and traffic volume and traffic accidents are reduced.
This study has investigated spatial and temporal impacts of rainfall intensity on traffic accidents in Hong Kong:

- The Thiessen-polygon approach is used to estimate more representative rainfall intensities at the locations with traffic accidents.
- The hourly periods with average rainfall intensities of 19 and 26 mm per hour are found to have the highest risk, when the increase in the number of accidents per hour is the greatest.
- A matched-pair dataset is used to analyze the hourly impacts of rainfall intensity on accidents, and found that the first hour of rain and the first hour after rain are the periods with the highest number of traffic accidents.

Further study can be carried out to investigate the impacts of rainfall intensity:

- to assess the temporal effects of rainfall by time of day or day of the week together with the spatial effects of accident severity by road type (with different speed limits and gradients) and by land use.

- to investigate the relationships between traffic speed, flow and density under various rainfall conditions on urban roads in Hong Kong.
The relationship between traffic speed and flow under various rainfall conditions
The relationship between traffic speed and density under various rainfall conditions

“Modeling the Effects of Rainfall Intensity on Traffic Speed-flow-density Relationships for Urban Roads”. ASCE Journal of Transportation Engineering, Manuscript #: TEENG-1616R2, accepted in 2013 for publication. (William H.K. Lam, Mei Lam Tam; Xinqing Cao; Xiangmin Li).
Thank You

Q and A

The 18th HKSTS International Conference
14-16 December, 2013, Hong Kong
http://www.hksts.org

多謝