A Review on Risk Levels Associated with LPG Filling Stations in Hong Kong

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Introduction
Background

- LPG filling stations have been constructed and operated across Hong Kong since 1998
- LPG filling stations are classified as Notifiable Gas Installation (NGI) in accordance to Gas Safety Ordinance Cap. 51
  - QRA is required to support the NGI construction application
Introduction
Hong Kong Risk Guidelines

- Individual Risk Guideline
  - Maximum level of off-site individual risk should not exceed $1 \times 10^{-5}$/year

- Societal Risk Guideline
  - Expressed in terms of fN curve
  - Three areas in the fN curve
    - Acceptable
    - Unacceptable
    - ALARP (As Low As Reasonably Practicable)
Societal Risk Guideline

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Objectives

- To identify dominant factors influencing the risk levels of LPG filling stations in Hong Kong
- To compare the planning standards and guidelines for LPG filling stations in Hong Kong
Methodology

- Review QRAs for 17 LPG filling stations
- QRAs were conducted following the methodology employed by the Gas Authority
- Use risk management software SAFETI (Micro v5.3.2)
- Assumptions
  - 90% of LPG road tanker delivery occurs during daytime
  - Nominal population at various locations was input into SAFETI
    - Conservative shielding factors
    - Occupancy factor for working and school population
    - Modification factor for indoor population in instantaneous release events
Methodology

- Potential Loss of Life (PLL) as the end point to compare risk levels among LPG filling stations
- Influencing factors investigated
  - Number of LPG storage vessel
  - Possible maximum amount of LPG release
  - Annual LPG throughput
  - Daytime nominal population around station
  - Night time nominal population around station
  - Separation distance from the station to the closest densely populated location
  - External events
Methodology

- Correlation analysis was applied to determine how strong the influencing factors and risk levels were related
## Results (Risk Level and Risk Influencing Factor at Stations)

<table>
<thead>
<tr>
<th>Stn Code</th>
<th>No. of storage vessels</th>
<th>Max. LPG Release (kg)</th>
<th>Annual Through-put (t)</th>
<th>External Event</th>
<th>Daytime Nominal Pop.</th>
<th>Night-time Nominal Pop.</th>
<th>Distance to the Closest Location with Nominal Population (m)</th>
<th>Potential Loss of Life (per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>15000</td>
<td>4437</td>
<td>-</td>
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<td>-</td>
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<td>631.9</td>
<td>42 42 114 174</td>
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<td>C</td>
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<td>10000</td>
<td>3618</td>
<td>Oil Depot Incident</td>
<td>3226.6</td>
<td>540.1</td>
<td>72 72 72 111</td>
<td>3.29E-5</td>
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<td>177.1</td>
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<tr>
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<td>3429</td>
<td>-</td>
<td>275.1</td>
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<td>There are village houses surrounding the station</td>
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<td>-</td>
<td>231.4</td>
<td>599.0</td>
<td>150 150 - -</td>
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<td>900</td>
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<td>1241.6</td>
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<td>10000</td>
<td>1593</td>
<td>Landslide</td>
<td>1322.7</td>
<td>4063.0</td>
<td>102 102 150 -</td>
<td>4.78E-6</td>
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<tr>
<td>I</td>
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<td>15000</td>
<td>360</td>
<td>Aircraft crash</td>
<td>186.3</td>
<td>588.9</td>
<td>175 175 - -</td>
<td>4.02E-6</td>
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<td>594.8</td>
<td>173 173 - -</td>
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</tbody>
</table>
### Results (Correlation Analysis)

<table>
<thead>
<tr>
<th>Risk Influencing Factor</th>
<th>Square of Correlation Analysis ($r^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum amount of LPG release</td>
<td>0.073</td>
</tr>
<tr>
<td>Annual LPG throughput of station</td>
<td>0.043</td>
</tr>
<tr>
<td><strong>Daytime nominal population within study area</strong></td>
<td><strong>0.704</strong></td>
</tr>
<tr>
<td>Night time nominal population within study area</td>
<td>0.011</td>
</tr>
<tr>
<td><strong>Reciprocal of distance between station and the closest location with nominal population &gt;50</strong></td>
<td><strong>0.889</strong></td>
</tr>
<tr>
<td>Reciprocal of distance between station and the closest location with nominal population &gt;100</td>
<td>0.449</td>
</tr>
</tbody>
</table>
Discussion

- Theoretical effect of influencing factor to risk level
  - Maximum LPG release ↑, risk level ↑ (consequence)
  - Annual throughput ↑, risk level ↑ (frequency)
  - Population around station ↑, risk level ↑ (consequence)
  - Separation distance to populated location ↓, risk level ↑ (consequence)
  - External event present, risk level ↑ (frequency)
  - Risk level of a station is determined by the combined effect of various factors
Discussions

- Observation from the review
  - Two factors appear to pose relatively large influence on predicted risk levels
    - Separation distance from station to the closest location accommodating large population
    - Daytime population around station
  - Other factors did not appear having strong relationship with the predicted risk levels
    - Night time population around station
    - Annual LPG throughput
Discussion

- Observation from the review
  - Effect of External Events
    - Landslide
      - Do not strongly influence the risk level
    - Aircraft crash
      - Seemed to contribute to the risk level considerably when the station is near airfield (aircraft landing/take off point)
      - The influence would depend on the distance to airfield (distance ↑, influence ↓)
Discussion

- The observations on the influencing factors are limited to the conditions of the 17 LPG filling stations reviewed
- How to avoid unacceptable risk posed by LPG filling station?
  - Allocate station sites away from densely populated areas
  - Allow considerable separation distance from populated location
  - Consistent with relevant planning standards and guidelines
Future Works

- Review more QRAs for LPG filling stations with application of more rigorous statistical analysis technique
- More information concerning influencing factors may help the development of some “rule of thumbs” to facilitate LPG filling site selection in the future
Conclusion

- Investigation on factors influencing risk levels of LPG filling stations
- Factors appeared to have more influential on risk level
  - Daytime population surrounding station
  - Separation distance from populated locations to station
Thank You!