Health Effects of Transportation Noise in Hong Kong: Findings of a Large Scale Survey

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Presentation to LegCo Panel on Environmental Affairs
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Health Effects of Transportation Noise in Hong Kong Study

• Commissioned by HK EPD

• Importance …. Hong Kong is unique
  – Compact and dense city
  – Possible cultural difference

• First city-wide large scale study in Asia using internationally accepted method and state-of-art noise mapping technology
Health Effects of Transportation Noise in Hong Kong Study

- **Study Team**
  - Lam Kin Che, CUHK (GRM, CUHK)
    - Environmental noise & project leader
  - Lex Brown, Griffith University (Australia)
    - Environmental noise, survey instrument, annoyance
  - Wong Tze Wai, CUHK (Public Health, CUHK)
    - Medical practitioner & noise-health effects
  - Irene van Kamp, Nat’l Institute of Public Health (Netherlands)
    - Epidemiology, public health & sleep disturbance
  - Chan Ying Keung, CUHK (Sociology, CUHK)
    - Statistician, social surveys
Objectives

• To review the non-auditory health effects, namely annoyance, sleep disturbance and cardiovascular diseases, based on the literature available from the WHO, EU and USA and other published scientific papers

• To look into the applicability and relevance of overseas results to the Hong Kong situation

• To study the annoyance effects due to transportation noise in Hong Kong, with the help of a household survey and a territory-wide noise mapping conducted respectively by the Census and Statistics Department (C&SD) and the Environmental Protection Department (EPD)
Methodology

- **Desk-top Review** of transportation noise-related health effects

- **Self-reported Annoyance & Sleep Disturbance:** Thematic Survey of Census & Statistics Department – 10,077 randomly selected households successfully interviewed

- **Exposure to Road Traffic Noise:** city-wide noise mapping
Scope of the Study

• Health Effects
  ▪ Review on annoyance, sleep disturbance & cardio-vascular diseases undertaken
  ▪ Survey on self-reported annoyance and sleep disturbance completed
  ▪ Self-reported cardio-vascular diseases not covered in this study

• Noise Exposure Assessment
  ▪ Focused on road traffic noise only
Findings

- **Desk-top Review** of transportation noise-related health effects

- **Self-reported Annoyance & Sleep Disturbance**: Thematic Survey of Census & Statistics Department
Potential Adverse Health Effects of Noise

• WHO Guidelines for Community Noise (1999)
  – Impact on auditory health
  – Interference with speech communication
  – Sleep disturbance
  – Performance effects
  – Annoyance
  – Cardiovascular effects
Annoyance

- "…a feeling of resentment, displeasure, discomfort, dissatisfaction, or offense when noise interferes with thoughts, feelings, or actual activities."

Annoyance at High Noise Levels

- "…should be considered a legitimate environmental health issue affecting the wellbeing and quality of life of the population…"

UK Health Protection Agency, 2009
Sleep Disturbance

• Sufficient evidence
  – Biological: increase in heart rate, arousals, sleep stage changes, hormone level changes and awakening
  – Self-reported sleep disturbance => increase in medicine use, body movements and insomnia

• Limited evidence
  – Disturbed sleep causes fatigue, accidents and reduced performance
  – Clinical conditions such as cardiovascular illness, depression and other mental illness

• Vulnerable group: children, elderly, pregnant women, shift workers, chronically ill
Disease and Environmental Noise

Blood pressure and heart diseases

• Growing evidence that environmental noise is associated with heart diseases
• Link with heart diseases is complicated by the presence of many other “confounding factors” that are also linked to heart diseases
• Link with hypertension has more evidence, but also influenced by “confounding factors”

Presented by Prof. TW Wong to LegCo Environmental Affairs Panel on 11th Jan 2013
Noise as a Potential Health Risk

- Supported by clinical studies in last 20 years
- Ascertained by several large scale surveys
  - HYENA
  - RANCH
  - ENNAH
- Reviewed by WHO experts
Noise – not just a feeling of discomfort
The Stress Model: Mechanism of the Noise Induced Effects (Babisch et al, 2001)

Noise Exposure (Sound Level)
- high
  - Direct pathway
    - Hearing loss
- moderate
  - Indirect pathway
    - Disturbances of activities, sleep, communication
    - Cognitive and emotional response
      - Annoyance

Stress Indicators
- Physiological stress reactions (unspecific)
  - Autonomic nervous system (sympathetic nerve)
  - Endocrine system (pituitary gland, adrenal gland)

Biological Risk Factors
- Blood pressure
- Cardiac output
- Blood lipids
- Blood glucose
- Blood viscosity
- Blood clotting factors

Manifest Disorders
Cardiovascular Diseases
- Hypertension
- Arteriosclerosis
- Ischaemic heart disease

Further Clinical Study
Findings

• *Desk-top Review* of transportation noise-related health effects

• *Self-reported Annoyance & Sleep Disturbance: Thematic Survey of Census & Statistics Department*
Pre-requisite to Achieve Goals

• Methodology which allows cross-country comparisons, e.g.:
  – Standardized question, wording and scales
  – Same / similar methodology as in other mega studies particularly with respect to the questions posed

• A scientific and robust approach is needed for comparison (Miedema et al., 2001)
The Survey

- 10,077 households covered
- “The question”?  
  - Used the “standard” question  
  - ISO 15666:2003
- How the question is posed?
  - Wording
  - Scale
    - 11-point scale
    - 5-point scale
  - Use of show card
The Exposure-Effect Curve

- Miedema & Oudshoorn (2001)
  - Synthesis of major studies producing exposure-effect curves
  - % Highly Annoyed
    - 8-10 on 10 pt scale

![Graph showing the relationship between traffic sound levels and percentage of highly annoyed individuals]
Information Obtained

- Annoyance/ Sleep Disturbance, with respect, separately, to
  - Road traffic noise
  - Rail noise
  - Aircraft noise
  - Other noise sources

- Other information which may help explain human response:
  - Personal: noise sensitivity, health conditions, coping behavior, sleep habits
  - Exposure: window/ air-conditioning, access to “quiet room”
  - Surrounding: satisfaction w/ neighborhood overall environment
  - Habituation: length of residence
QA/QC – Pilot Test of Questionnaire

• Two Pilot studies by CUHK Team (n >100)
  – Refinements of questions
  – Testing of Cantonese terms
  – Use of show cards
Translation and back-translation: English to Cantonese

• Need for standardization
  – From English to other languages

• How?
  – Use of words for “Annoy”, “Bother”, “Disturb”

  • Start with the Mandarin of Ma (2003) => Cantonese
  • Tried out on CUHK students in Pilot Study I

• Back translation: E->C->E
QA/QC – Random Sub-sample
Check of Households Interviewed

• Follow-up calls to confirm answers on selected questions, e.g.
  – Annoyance - “Did surveyor ask you about…?”
    → Yes/ No
  – No. of rooms in household
    → Fill in exact no.
  – Quiet room?
    → Yes/ No
Noise Exposure Estimation

• Type of transport noise modeled
  – Road traffic

• Methodology
  – Noise mapping with respect to road traffic noise
  – Confidentiality of household addresses kept

• Noise metrics modeled
  – Road traffic – $L_{DEN}$, $L_{night}$
Technique of Noise Mapping

**Input**
- Propagation Path
  - Building footprints
  - Podiums
  - Barriers
  - Enclosures
  - Spot heights
  - Contour lines
  - Rivers
  - Slope tops/bottoms
  - Vegetation (ground absorption)
- Emitters
  - Railway tracks
  - Road centreline
  - Airport
- Traffic Model
  - # of vehicles
  - Speed
  - Vehicle weight

**Processing**
Noise Exposure Software
Calculates noise levels in different areas using inputs

**Output**
- Level of exposure estimated for various areas;
- 3-D visualization
- Obtain façade noise exposure of over 10,000 addresses
Example of Modeling Results
Façade Noise from Road Traffic
Key Questions

• Which noise annoys Hong Kong people most?
• How many people are affected?
• How does Hong Kong people’s response compare with that of others?
• Other than noise exposure, what other factors affect annoyance and sleep disturbance?
• What are the implications of these findings?
Which Noise Annoys HK People Most?

- “Highly Annoyed” = 8 to 10 on 0 to 10 scale

<table>
<thead>
<tr>
<th>Noise Source</th>
<th>% Highly Annoyed (HA)</th>
<th>% Highly Annoyed at Night (HAN)</th>
<th>% Sleep Highly Disturbed (HSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road traffic</td>
<td>7.9</td>
<td>4.95</td>
<td>4.15</td>
</tr>
<tr>
<td>MTR, trains or LRT</td>
<td>0.7</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Aircraft</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Industries/ factories/ machineries</td>
<td>0.5</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Commercial activities</td>
<td>1.6</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Construction/ demolition</td>
<td>3.4</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Renovation</td>
<td><strong>10.8</strong></td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Neighbor’s air conditioning</td>
<td>1.4</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Neighbors</td>
<td>3.5</td>
<td>1.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Playgrounds/sports ground</td>
<td>1.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Outside animals</td>
<td>1.8</td>
<td>1.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>
Key Questions

• Which noise annoys Hong Kong people most?
• How many people are affected?
• How does Hong Kong people’s response compare with that of others?
• Other than noise exposure, what other factors affect annoyance and sleep disturbance?
• What are the implications of these findings?
How many people in HK are affected?

- Percent households with most exposed side of dwelling exceeding noise criterion:
  - HK Planning Standard $L_{10,1h}$ 70 dBA: 28.9%
  - WHO $L_{DEN}$ 65 dBA: 36.2%

- Number of adult population affected **

<table>
<thead>
<tr>
<th></th>
<th>% of Population</th>
<th>Confidence Interval (%)</th>
<th>Estimated Number of Population Aged 18 or Above (in thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td>Highly Annoyed</td>
<td>7.9</td>
<td>±0.526</td>
<td>432.6-491.1</td>
</tr>
<tr>
<td>Highly Annoyed Night</td>
<td>4.95</td>
<td>±0.42</td>
<td>265.9-315.2</td>
</tr>
<tr>
<td>Highly Sleep Disturbed</td>
<td>4.13</td>
<td>±0.39</td>
<td>219.5-165.3</td>
</tr>
</tbody>
</table>

** With reference to most exposed side of dwelling
Exposure of the Hong Kong Population to Road Traffic Noise

- More than 35% of the population have the **most exposed side of their dwelling** exposed to $L_{DEN} > 65$ dB(A)

- **Note:**
  - * Most exposed side
  - * External facade
Key Questions

• Which noise annoys Hong Kong people most?
• How many people are affected?
• How does Hong Kong people’s response compare with that of others?
• Other than noise exposure, what other factors affect annoyance and sleep disturbance?
• What are the implications of these findings?
Comparing the HK Exposure - Highly Annoyed Curve with Miedema’s
Comparing the HK Exposure - % Highly Sleep Disturbed Curve with Miedema’s
Comparison of Hong Kong and Vietnam Curves
Key Questions

• Which noise annoys Hong Kong people most?
• How many people are affected?
• How does Hong Kong people’s response compare with that of others?
• Other than noise exposure, what other factors affect annoyance and sleep disturbance?
• What are the implications of these findings?
Statistical Analysis

- Binary logistics ordinal regression
  - Binary dependent variable: Highly Annoyed (HA) or not / Highly Sleep Disturbed (HSD) or not?

- With respect to road traffic noise
  - 24h ($L_{DEN}$) & at night ($L_{NIGHT}$) respectively

- Key predictor variables
  - Noise exposure - $L_{DEN}$, $L_{night}$

- Confounding factors (ordinal)
  - As found in previous studies, results described in next two slides
Factors Affecting whether the Respondent is Highly Annoyed

Results of binary logistic ordinal regression

<table>
<thead>
<tr>
<th>Description</th>
<th>Beta coefficient</th>
<th>Level of significance</th>
<th>Odds ratio</th>
<th>Cumulative Nagelkerke R Square</th>
<th>Change in Nagelkerke R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Noise exposure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise exposure (L_DEN)</td>
<td>.74</td>
<td>.000</td>
<td>1.077</td>
<td>.058</td>
<td>/</td>
</tr>
<tr>
<td><strong>Physical factors affecting noise exposure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to quiet room</td>
<td>-.758</td>
<td>.000</td>
<td>.469</td>
<td></td>
<td></td>
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<tr>
<td>Closing window</td>
<td>.257</td>
<td>.000</td>
<td>1.293</td>
<td>.088</td>
<td>.03</td>
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<tr>
<td>Number of household</td>
<td>-.275</td>
<td>.005</td>
<td>.760</td>
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<tr>
<td><strong>Personal factors affecting perception</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction with neighbourhood environment</td>
<td>-.602</td>
<td>.000</td>
<td>.548</td>
<td>.119</td>
<td>.031</td>
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<tr>
<td>Ownership</td>
<td>.218</td>
<td>.008</td>
<td>1.244</td>
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<tr>
<td><strong>Other personal factors</strong></td>
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<tr>
<td>Interviewee's noise sensitivity</td>
<td>.453</td>
<td>.000</td>
<td>1.573</td>
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<tr>
<td>Hearing problems</td>
<td>.481</td>
<td>.012</td>
<td>1.618</td>
<td>.140</td>
<td>.021</td>
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<tr>
<td>Education Level</td>
<td>.132</td>
<td>.032</td>
<td>1.141</td>
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</tr>
</tbody>
</table>

Odds Ratio

- $> 1$
- $< 1$
## Factors Affecting whether the Respondent is Highly Sleep Disturbed

- Results of **binary logistic ordinal regression**

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<thead>
<tr>
<th>Description</th>
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<td><strong>Noise exposure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise exposure (L_DEN)</td>
<td>.086</td>
<td>.000</td>
<td>1.089</td>
<td>.057</td>
<td></td>
</tr>
<tr>
<td><strong>Physical factors affecting noise exposure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to quiet room</td>
<td>-.821</td>
<td>.000</td>
<td>.440</td>
<td>.083</td>
<td>.026</td>
</tr>
<tr>
<td>Number of household</td>
<td>-.350</td>
<td>.014</td>
<td>.704</td>
<td></td>
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</tr>
<tr>
<td><strong>Personal factors affecting perception</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction with neighbourhood environment</td>
<td>-.460</td>
<td>.000</td>
<td>.631</td>
<td>.099</td>
<td>.016</td>
</tr>
<tr>
<td><strong>Other personal factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interviewee's noise sensitivity</td>
<td>.715</td>
<td>.000</td>
<td>2.044</td>
<td>.139</td>
<td>.04</td>
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<tr>
<td>Education level</td>
<td>.201</td>
<td>.012</td>
<td>1.222</td>
<td></td>
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</tbody>
</table>

Odds Ratio
- $> 1$
- $< 1$
Key Questions

- Which noise annoys Hong Kong people most?
- How many people are affected?
- How does Hong Kong people’s response compare with that of others?
- Other than noise exposure, what other factors affect annoyance and sleep disturbance?
- What are the implications of the study findings?
  - From source control to innovative building design
  - Recognize limitation of over-reliance on noise reduction
  - Crafting a pleasant holistic sound environment
Ways to Reduce Noise Exposure

1. Source - traffic volume & composition
2. Noise Path - noise barriers
3. Receiver - building & window design
How Many Cars Have to be Removed?

- Assuming the noise criterion is $L_{DEN} \ 65 \ \text{dB}(A)$

To reduce noise by 3 dB, traffic flow has to be cut by half
THE JOINT HKIOA-PolyU ONE-DAY SYMPOSIUM

RESEARCH, ASSESSMENT AND DEVELOPMENT OF APPLYING INNOVATIVE BUILDING DESIGNS FOR NOISE MITIGATION- THE LATEST TRENDS

Gold Sponsor
KINETICS
Noise Control

Silver Sponsor
ENVIRON
Noise Exposure – Effect Curves

% Highly Annoyed

Noise Level

Western Cities

Hong Kong

A

B

X
Use of Exposure – Effect Curve for Noise Standard Setting

WHO Community Noise Guidelines (1999):
“Serious annoyance”

Percent highly annoyed (HA) [%]

Noise level (L_{den,24h}) [dBA]
Influence of Slope of Exposure-Effects Curve on Annoyance

Miedema Curve

Hong Kong
What does this study say?

- Effect of noise exposure is limited
- Intensifying annoyance
  - Ill-health
  - Noise sensitivity
- Moderating annoyance
  - Good neighborhood environment
  - Access to a “quiet room”
Human annoyance at home and outside their residence and interactions among the effects

- Dwelling
- Neighbourhood
- Community
Wanted and Unwanted Sound in Cities

- **Unwanted - Noise**
  - Road traffic
  - Industries

- **Wanted**
  - Bird songs
  - Water sound
wanted ‘natural sounds’

ambient generated by distant traffic

occasional noticeable noise peaks

Partial Masking

Source: A.L. Brown
UK’s Department for Environment, Food and Rural Affairs

Research into the Practical and Policy Applications of Soundscape Concepts and Techniques in Urban Areas (October 2009)

Approaches to Soundscape Design

- Control negative sound sources
  - Remove, buffer and mitigate
- Preserve and enhance existing positive sound sources
- Add sounds to alter the soundscape or detract attention from existing soundscape features
  - Water sounds, sonic art installation, etc.
Watch Out - Noise-related Health Risks are Increasing (Irene van Kamp, 2010)
Thank you.