Review of Vehicle Emission Modelling and the Issues for New Zealand

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Outline

• Classification and application of vehicle emission models
• Key European and American models
  • NAEI
  • COPERT
  • HBEFA
  • ARTEMIS
  • MOBILE
• Two NZ models
  • VFEM (MoT)
  • VEPM (ARC)
• Conclusions and recommendations
Classification of vehicle emission models

- Aggregated emission factor models (e.g. MAEI, MOBILE)
- Average speed models (COPERT, ARC’s VEPM)
- Traffic situation models (HBEFA, ARTEMIS, MoT’s VFEM)
- Instantaneous or modal models (PHEM)
Traffic situation model (in ARTEMIS)

- **TS**: Traffic Situations
- **DP**: Driving Patterns
- **RTP**: Reference Test Patterns

Diagram:
- **TS**: Traffic Situations
  - **All Vehicle Categories**
    - **DP**: Driving Patterns
      - **PC**
      - **HDV**
      - **MC**
    - **RTP**: Reference Test Patterns
      - **PC**
## Applications of vehicle emission models

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<th>Macro scale (at fleet level)</th>
<th>Micro scale (very local)</th>
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<td><strong>Absolute estimates</strong> (e.g. emission inventories)</td>
<td>e.g. national or regional inventories</td>
<td>e.g. street air pollution dispersion analysis</td>
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<tr>
<td><strong>Differential estimates</strong> (e.g. scenario testing, EIA)</td>
<td>e.g. national emission control policy assessment</td>
<td>e.g. transport project assessment</td>
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Advantages

☑ Model many pollutants from different processes
☑ Good emission factors for light vehicles (very large datasets, based on ‘real-world” European driving cycles)

Issues

☑ Emission factors for heavy vehicles are not that good
☑ (Emission-average speed functions -- all road types together)

Relevance to NZ

Primary source for emission factors of light vehicles in VEPM
Advantages

- Good emission factors for both light and heavy vehicles
- Separate sets of emission-average speed functions for three road types

Issues

- Non-exhaust PM emissions – large uncertainty (common for all?)
- Emission factors for newer technology vehicles?

Relevance to NZ

Primary source (COPERT III database) for emission factors of heavy vehicles and cold-start in VEPM
Handbook Emission Factors for Road Transport

Advantages

✓ Developed a traffic situation approach
✓ Normalisation procedure in PHEM and the software “Art.combino” can be very useful

Issues

Emission factors applicable mainly to Germany, Switzerland and Austria

Relevance to NZ

Not much except the methodology
Advantages

✓ The largest emission database to date
✓ Improved a lot over COPERT and HBEFA

Issues

(based on European driving behaviour and traffic situations)

Relevance to NZ

Data and methodologies may be borrowed
Advantages

✓ Model freeway ramps separately from freeways
✓ Consider the effects of gross emitters

Issues

✓ BERs based on FTP rather than “real-world” driving cycles
✓ No engine size breakdown for light vehicles

Relevance to NZ

Fleet quite different from NZ but methodologies merit further consideration

Average % of motorway VKT on the ramps
USA: 8%
Auckland: 11%
Wellington: 10%
NZ’s vehicle emission testing programmes

• In late 1990s, MoT’s VFECS and MfE’s SMF (more than 10 driving cycles for each light vehicle):
  ✓ 23 light petrol
  ✓ 11 light diesel
  ✓ 4 heavy diesel trucks

• In 2004, for MoT (3 driving cycles for each light vehicle):
  ✓ 61 light petrol
  ✓ 22 light diesel
  ✓ 4 heavy diesel
VFEM – Vehicle Fleet Emissions Model

- Developed in late 1990s (outputs packaged in NZ-TER)
- A traffic situation model – 12 traffic situations were defined (4 road types × 3 levels of service)
- Aimed to be used for scenario tests
- The vehicle fleet and traffic sub-models have been revised several times – acceptable
- Widely used in NZ
VFEM – Key Issues

• The underlying emission factors data poorly documented - a black/grey box?
  – Emission factors were likely from overseas databases and “calibrated” using the data of the 1st NZ programme
• Emission factors have not been updated since the model was developed more than ten years ago
• Only 12 traffic situations defined (>200 TSs in ARTEMIS)
VEPM – Vehicle Emissions Prediction Model

- Recently developed and well documented – Version 3.0 is available now
- Best suited for scenario tests
- Primary sources of emission factors – European databases:
  - ✓ NAEI for light vehicles
  - ✓ COPERT III for heavy vehicles and cold-start emissions
- For non-European vehicles – “calibrated” by drawing “equivalencies”:
  - ✓ JCAP I (1997-2001) for Japanese vehicles
  - ✓ The 2nd NZ emission testing data for NZ vehicles
VEPM – Key Issues

- Based mainly on European data
- Drawing “equivalencies” for non-European vehicles may have caused errors (could be fairly large for some categories)
- More new overseas data have been available since VEPM was developed, e.g.
  - JCAP II
  - COPERT 4
  - ARTEMIS
A Key Issue for NZ When Using Overseas Data

Do the vehicles with different country origins have similar emission behaviours while driving in the same pattern even though they were built to a “similar” emission standard?

- Australian (ADR), Japanese, EU (Euro) and US emission standards:
  - have different limit values
  - introduced in different years
  - based on different driving cycles

Need to model the vehicles with different origins SEPARATELY and PROPERLY
But what standards are NZ vehicles built to?

Only 16% are built to Euro Standards

What emissions standards are NZ vehicles built to?

- Japanese domestic: 49%
- Euro (post 2004): 16%
- Unknown (NZ New pre-2004): 35%

Are we looking for something in the wrong place?

**Drive cycle differences**

**Japanese 10-15 mode cycle**

- Time (s): 1, 60, 119, 178, 237, 296, 355, 414, 473, 532, 591, 650, 709, 768, 827, 886
- Speed (km/h): 80

**European combined cycle**

- Time (s): 1, 103, 205, 307, 409, 511, 613, 715, 817, 919, 1021, 1123
- Speed (km/h): 140

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**Japan = Warm start**  
Max speed 70km/h

**Euro = Cold start (since 2000/Euro 3)**  
Max speed 120 km/h

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**New Zealand-new vehicles**  
- CO idle: 2.5  
- CO Part load (2,500 RPM): 2.0

**Japanese-used vehicles**  
- CO idle: 2.0  
- CO Part load (2,500 RPM): 1.5

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Only 11% of sample would have passed a European In-service emissions test, but 72% would pass Japanese test

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Conclusions and Recommendations (1)

- Different models are best suited to different applications (spatial/temporary scales, absolute/relative estimates)

- Both NZ models (VFEM & VEPM) have significant room for improvement as to the accuracy of emission factors for the unique NZ vehicle fleet

- Emission data for the NZ fleet are limited especially for heavy vehicles. Overseas data will continue to be needed

- Modelling emissions from a large group of “New Zealand–new” vehicles could be a big issue

- Would be more logical to base a NZ model on Japanese emission data
Conclusions and Recommendations (2)

- Differences in actual driving dynamics and traffic conditions also need to be considered when using overseas data (“Art.combino” could be useful)

- Emission testing for heavy vehicles/engines is expensive and relevant data are limited worldwide. A normalisation procedure for engine maps developed in PHEM could be useful in deriving emission factors for heavy vehicles

- ARTEMIS and Australian data merit further investigation
Thank you for your time!

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