Evaluating Bus Emissions
What colour, how big and how much is that elephant in the window?

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While costing **operational elements** of a passenger transport service is relatively well understood, costing **environmental externalities** is less so and often regarded as the “**elephant in the room**” ... 

... or the window
Evaluating Greater Wellington (GW) Bus Fleet Emissions

- Why is there a need to understand elephants?
- What colour is the elephant?
- How big is the elephant?
- How much does the elephant cost?
- What have we learnt about elephants?
Why the need to understand elephants?

- Wellington has a strong culture of public transport use – around 74 trips per capita
- Growing public desire for sustainable, clean public transport solutions
- In 2016, GW commenced tendering for bus services under the new Public Transport Operating Model (PTOM) for nine contract areas with new fleets to be in place by 2018
- Tender included incentives for low emission fleets
Why the need to understand elephants?

- **Existing fleet relatively old**, made up of diesel buses and, until recently, some electric trolley buses
- Over 50% of fleet planned to be replaced when new PTOM contracts start *(outcome achieved higher than this)*
Why the need to understand elephants?

- To encourage lower emission vehicles and move to an all-electric bus fleet, GW created an **Emission Improvement Premium (EIP)** as part of tender evaluation.
What colour is the elephant?

- Road transport greenhouse gas emissions ($CO_{2-e}$) have grown steadily since 1990 - 78% up in 2015
What colour is the elephant?

- **Harmful emissions** of most concern include:
  - Particulate matter (PM\textsubscript{10})
  - Nitrogen dioxide (NO\textsubscript{2})
  - Carbon monoxide (CO)
  - Hydrocarbons (HC)

- Most health effects from PM\textsubscript{10} but increasing concern about NO\textsubscript{2}
How big is the elephant?

- For GW modelling, focussed on tailpipe (only) emissions of CO$_2$, PM$_{10}$, NO$_x$, CO and HC

- How much an individual bus emits depends on:
  - **Fuel** type (e.g. diesel, hybrid, natural gas etc.)
  - Emissions control **technology** (e.g. Euro IV, Euro IV etc.)
  - **Size** and tare **weight** (e.g. small, double decker etc.)
  - Passenger **capacity** and average **loading**
  - Average **speed** and **distance** travelled
How big is the elephant?

- Base factors from COPERT (average speed model)
- Bus types aligned to closest COPERT equivalent then **adjusted by operating mass**
- Developed factors for **alternative fuels** and **technologies** e.g. compressed natural gas, diesel-hybrids, low carbon emission buses etc.
- Calculated **emissions/yr for each tender fleet** from:
  - Emission Factors (each bus type offered, route speed)
  - VKT (each bus type offered, assumed VKT evenly divided by bus #s)
How big is the elephant?

- Example from the model – emission factors for a large bus travelling at 20 km/hr

<table>
<thead>
<tr>
<th>Bus type</th>
<th>Bus size</th>
<th>Emission Factors in g/km @ 20km/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CO</td>
</tr>
<tr>
<td>Euro III</td>
<td>Large (LV)</td>
<td>3.46</td>
</tr>
<tr>
<td>Euro IV</td>
<td>Large (LV)</td>
<td>1.61</td>
</tr>
<tr>
<td>Euro V</td>
<td>Large (LV)</td>
<td>2.82</td>
</tr>
<tr>
<td>Euro VI</td>
<td>Large (LV)</td>
<td>0.33</td>
</tr>
<tr>
<td>Euro V diesel hybrid</td>
<td>Large (LV)</td>
<td>2.82</td>
</tr>
<tr>
<td>Euro VI diesel hybrid</td>
<td>Large (LV)</td>
<td>0.33</td>
</tr>
<tr>
<td>Low carbon emission bus</td>
<td>Large (LV)</td>
<td>0.03</td>
</tr>
<tr>
<td>Electric</td>
<td>Large (LV)</td>
<td>0</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Large (LV)</td>
<td>1.12</td>
</tr>
</tbody>
</table>
How much does the elephant cost?

- Utilised **damage costs** (social costs) as a way to value differences in air emissions from fleets
- Started with **Austroads (2012)** figures:

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Costs in AUD/tonne</th>
<th>Value Base Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>$52.40</td>
<td>2010</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>$332,505.90</td>
<td>2010</td>
</tr>
<tr>
<td>NOₓ</td>
<td>$2,089.20</td>
<td>2010</td>
</tr>
<tr>
<td>CO</td>
<td>$3.30</td>
<td>2010</td>
</tr>
<tr>
<td>HC</td>
<td>$1,046.80</td>
<td>2010</td>
</tr>
</tbody>
</table>

- Then updated with recent literature, costs at 2015
How much does the elephant cost?

- **PM$_{10}$** based on HAPINZ costs linked to emissions (2015) then adjusted using road safety VoSL
- **NO$_x$** based on UK DEFRA (2015) then pro-rated emissions/effects versus PM$_{10}$
- **CO, HC and CO$_2$** left as Austroads (2012) values

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Costs in NZD/tonne</th>
<th>Value Base Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$</td>
<td>$65.99</td>
<td>2015</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>$451,123</td>
<td>2015</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>$16,031</td>
<td>2015</td>
</tr>
<tr>
<td>CO</td>
<td>$4.16</td>
<td>2015</td>
</tr>
<tr>
<td>HC</td>
<td>$1,318</td>
<td>2015</td>
</tr>
</tbody>
</table>
What did we learn about elephants?

• As expected, overall emission costs decrease with cleaner technologies (except for Euro V at lower speeds)
What did we learn about elephants?

- Outcome delivered an **89% improvement** in harmful emissions vs the minimum specified requirement
Being able to **understand and value** “elephants” means we can all tread more lightly into the future...

Thank you for listening!