Appendix 1 Evidence Tables

Question 5: Are traffic management systems and signal coordination interventions effective at reducing the health impact of, or people’s exposure to, traffic-related air pollution?

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>Full citation
Casale, Federico, Nieddu, Gianluigi, Burdino, Elisa, Vignati, Davide, Ferretti, Carlo, Ugazio, Giancarlo, Monitoring of Submicron Particulate Matter Concentrations in the Air of Turin City, Italy. Influence of Traffic-limitations, Water, Air & Soil Pollution, 196, 141-149, 2009

Quality score
-

Study type
Controlled study

Aim of the study
To evaluate the effect of traffic restrictions in a city centre on Particulate Matter pollution concentrations.

Location and setting
Turin, Italy

Length of study
Samples were collected over 7 weeks in the period April 2004–February 2005

Source of funding
Grant from the Piedmont Regional Government, Italy</td>
<td>Participant characteristics
The traffic-limited zone (“ZTL”—Zona a Traffico Limitato) covers an area of 1.03 km^2 with 12,500 inhabitants.

Inclusion criteria
Not reported

Exclusion criteria
Not reported</td>
<td>Intervention / Comparison
Vehicle circulation in the traffic-limited zone (ZTL - Zona a Traffico Limitato) was restricted in the city centre from 10:00am to 7:00pm on 'ecological days' (typically Sundays). The restriction applied to diesel and gasoline vehicles with exceptions, including public transport, emergency and operative vehicles. Weeks 1 to 5 of the study were planned with traffic limitation (ecological Sundays), while no limitations were enforced (normal traffic density) in weeks 6 and 7.
Average PM_{10} levels from the regional air quality authorities were measured for comparative purposes with sampling data (PM_{10} data not reported).</td>
<td>Outcomes

PM_{10} determinations ($\mu g/m^3$) in the urban centre (data from regional air quality authorities - daily mean of the 24 h)
<table>
<tr><th>Week</th><th colspan="6">Day of sampling*</th></tr>
<tr><td></td><td>Thursday</td><td>Friday</td><td>Saturday</td><td>Sunday</td><td>Monday</td><td>Tuesday</td></tr>
<tr><td>1</td><td>40</td><td>11</td><td>22</td><td>33</td><td>13</td><td>29</td></tr>
<tr><td>2</td><td>32</td><td>29</td><td>40</td><td>29</td><td>34</td><td>76</td></tr>
<tr><td>3</td><td>27</td><td>26</td><td>26</td><td>21</td><td>26</td><td>29</td></tr>
<tr><td>4</td><td>52</td><td>41</td><td>30</td><td>22</td><td>42</td><td>65</td></tr>
<tr><td>5</td><td>89</td><td>103</td><td>109</td><td>49</td><td>46</td><td>44</td></tr>
<tr><td>6</td><td>58</td><td>42</td><td>30</td><td>41</td><td>52</td><td>50</td></tr>
<tr><td>7</td><td>55</td><td>75</td><td>90</td><td>87</td><td>38</td><td>79</td></tr>
</table>
Intervention on Sundays; No intervention in weeks 6 and 7.
* Day of sampling, from Thursday to Tuesday of each week.

Analysis
Concentrations of PM_{10}, as measured by the regional quality authorities, showed a general reduction on the intervention days for 2 out of the 5 weeks.</td>
<td>Limitations identified by the author
Data collection was occasionally prevented due to technical problems or road closures.

Limitations identified by the review team
No specific data was reported on the concentrations of PM_{10} and $PM_{2.5}$ inside and outside of the ZTL by the authors (only graphs published).</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr>
<td>Full citation
Layfield, R., Nicholls, D., Transport Research, Laboratory, Chinn, L., Pilot home zone schemes: evaluation of The Methleys, Leeds, TRANSPORT, 2003

Quality score
-

Study type
Controlled before and after

Aim of the study
To determine the effect of traffic calming measures within the Pilot home zone scheme on air pollutant concentrations.

Location and setting
Leeds, UK

Source of funding
The Home Zone Pilot programme was set up and funded by the Department for Transport. TRL was commissioned by the DfT to evaluate the programme.</td>
<td>Participant characteristics
Monitoring sites were located at the kerbside close to where the installation of safety measures were proposed. The sites were located at the kerbside close to the emissions source. Four sites were chosen, 2 locations with a site on each side of the road.
A control site was also used to enable a distinction between changes in air quality due to the traffic management measures and changes due to other effects.

Inclusion criteria
Not reported

Exclusion criteria
Not reported</td>
<td>Intervention / Comparison
Traffic calming measures were introduced on key streets to reduce vehicle speed:
1. Speed cushions
2. Road narrowing
3. Road chicane layout

Monitoring of NO$_2$ was carried out for 2 week periods before the installation of the traffic calming schemes (31 May 2000 to 7 November 2000) and after the work had been completed (29 May 2002 to 4 November 2002).</td>
<td>Outcomes

Mean NO$_2$ concentrations (μg m^3) before and after the scheme
<table>
<tr><th></th><th></th><th></th><th colspan="2">Change</th><th>Statistically significant?</th></tr>
<tr><th>Monitoring site</th><th>Before</th><th>After</th><th>μg m^3</th><th>%</th><th></th></tr>
<tr><td>1 Methley Drive South</td><td>11.78</td><td>13.40</td><td>1.62</td><td>+14</td><td>No</td></tr>
<tr><td>2 Methley Drive North</td><td>16.32</td><td>13.13</td><td>-3.19</td><td>-20</td><td>No</td></tr>
<tr><td>3 Blake Grove East</td><td>18.58</td><td>15.85</td><td>-2.73</td><td>-15</td><td>No</td></tr>
<tr><td>4 Blake Grove West</td><td>18.15</td><td>16.03</td><td>-2.12</td><td>-12</td><td>No</td></tr>
<tr><td>5 Urban background control site</td><td>14.43</td><td>13.62</td><td>-0.81</td><td>-6</td><td>No</td></tr>
</table>
To determine the significance of the differences observed, t-tests were employed which assumed concentrations at each of the locations and within each study were independent of each other. A difference was said to be significant at the 5 per cent level.

Analysis
The control site showed a decrease in NO$_2$ concentration of 6%, whereas 3 kerbside sites showed a decrease in concentration ranging 12% to 20%. One kerbside site showed an increase of 14% although the authors thought that this was likely to be due to the ‘before’ data for this site being limited to the earlier part of the ‘before’ survey because of the diffusion tubes being stolen. None of these changes, however, were statistically significant.</td>
<td>Limitations identified by the author
Due to sample tubes being repeatedly stolen, sampling was discontinued at site 1 during the before intervention sampling period.
In both periods there is evidence of seasonal variation with external factors such as weather conditions affecting concentration levels at all of the sites.

Limitations identified by the review team
The siting of the sample tubes for sites 1 and 2 were not where the speed cushions were sited.
There are gaps in the data where none is reported for site 2 during the before intervention sampling period.</td>
</tr>
<tr>
<td>Full citation
Lee, B. K., Jun, N. Y., Lee, H. K., Analysis of impacts on urban air quality by restricting the operation of passenger vehicles during Asian Game events in Busan,</td>
<td>Participant characteristics
Not reported

Inclusion criteria
Not reported

Exclusion criteria</td>
<td>Intervention / Comparison
Passenger numbers in Busan were not allowed to operate on the alternative days during the AG period.</td>
<td>Outcomes

Percentage change in air pollution levels during the alternate operation of passenger vehicles compared to those before the operation
<table>
<tr><th></th><th colspan="2">Reduction (-) or increase (+) of pollutant (%)</th></tr>
<tr><th></th><th>NO$_2$</th><th>PM$_{10}$</th></tr>
<tr><td>Arithmetic Mean (AM)[1]</td><td>+47.8</td><td>+53.8</td></tr>
</table></td>
<td>Limitations identified by the author
The average usage rate of passenger vehicles under alternate (restricted) operation was 95.4%. Vehicle operation speed</td>
</tr>
</table>

Study details	Population	Intervention / Comparator	Results	Notes
Korea, Atmospheric Environment, 39, 2323-2338, 2005 **Quality score** - **Study type** Controlled before and after **Aim of the study** An analysis of the impacts on urban air quality of restricting the operation of passenger vehicles during the 24th Asian Games. **Location and setting** Busan, Republic of Korea **Source of funding** University of Ulsan, Korea.	The concentrations measured on rainy days with precipitation above 3.5 mm per day were excluded to evaluate the net effects of the alternate operation of passenger vehicles.	Even number cars, based on the last title number of a car, were only allowed to operate on the even days and odd number cars were also only allowed to operate on the odd days. 1 hour average concentrations of NO_2 and PM_{10} were conducted at 13 monitoring sites in Busan during the 3 periods studied: • Before the AG period (13-28 September 2002). • During the AG period when the intervention was in operation (29 September - 14 October 2002), and; • After the AG period (15-30 October 2002). Based on the 1 hour average levels, the 24 hour and 16 day average levels were calculated and compared. **Comparator** Air pollution levels were also measured in Ulsan, a city 30 km from Busan with similar meteorological conditions.	**Standard deviation**[1] | +25.1 | +14.8 **Maximum**[1] | +84.1 | +85.5 **Minimum**[1] | -1.4 | +26.5 **AM in Ulsan** | +17.2 | +36.3 **AM difference (Busan-Ulsan)** | +30.6 | +17.5 [1] Excluded the data measured on days with precipitation about 3.5 mm in Busan. **Analysis** Average levels of NO_2 and PM_{10} increased during the period of the intervention compared to those in the period before. air pollution levels also increased in Ulsan during the AG compared to before, however, the degree of increase was less than that in Busan.	increased approximately 28.1% as compared to normal periods. The authors note this would have resulted in increased emissions of NO_2. The main cause of these increases was strongly related to a change of meteorological conditions; reduction in average daily ambient ventilation index, maximum mixing height, and wind velocity during the alternate operation period. Busan has a very busy international shipping port. Highest source of air pollutant emissions in the city is from shipping.
Full citation Levy, I., A national day with near zero emissions	**Number of participants** N/A	**Intervention / Comparison** On the National Jewish	**Outcomes** **Average daily maximum and minimum levels of NO2 (ppbv) over 15 years as well as the range (maximum - minimum) of non-DA vs. DA days. Number in**	**Limitations identified by the author** It is difficult to assess the

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>and its effect on primary and secondary pollutants, Atmospheric Environment, 77, 202-212, 2013

Quality score
-

Study type
Before and after

Aim of the study
To examine the short term effects of a drastic change in emissions on a national scale during the Jewish holiday of Day of Atonement (DA) in Israel.

Location and setting
Israel

Source of funding
European Union Seventh Framework Programme</td>
<td>Participant characteristics
3 sampling sites were chosen.

Two sites in Tel Aviv with a population of approximately 1.2 million:
1. Tel Aviv central bus station (CBS) - a heavily polluted urban core with busy traffic and intensive commercial activities.
2. Urban Background site - sited in a residential area of Tel Aviv (UBG)

A third site in the town of Modi'in, 27 km east of Tel Aviv with a population of approximately 40,000 residents (DWN)

Inclusion criteria
Not reported

Exclusion criteria
Not reported</td>
<td>holiday of Day of Atonement (DA) there is the cessation of nearly all vehicles (with the exception of on-duty emergency vehicles) and commercial, industrial and recreational activities for approximately a 25 hour period.
Levels of NO_2 were compared for historical data over a 15 year period (1998-2012).

In-depth study of 1 year (2001) also carried out. Year chosen because of persistent meteorological conditions before and during DA.

Comparator
Normal working day</td>
<td>brackets is the percent change from non-DA to DA (DA/non-DA - 1)
<table>
<tr><th></th><th colspan="3">CBS</th><th colspan="3">UBG</th><th colspan="3">DWN</th></tr>
<tr><th></th><th>Non-DA</th><th>DA</th><th>% Change</th><th>Non-DA</th><th>DA</th><th>% Change</th><th>Non-DA</th><th>DA</th><th>% Change</th></tr>
<tr><td>Maximum</td><td>41.2</td><td>7.0</td><td>-83%</td><td>27.4</td><td>10.5</td><td>-62%</td><td>25.1</td><td>5.8</td><td>-77%</td></tr>
<tr><td>Minimum</td><td>15.3</td><td>1.1</td><td>-93%</td><td>3.0</td><td>0.5</td><td>-83%</td><td>7.8</td><td>0.9</td><td>-88%</td></tr>
<tr><td>Difference</td><td>25.9</td><td>5.9</td><td></td><td>24.4</td><td>10</td><td></td><td>17.3</td><td>4.9</td><td></td></tr>
</table>

2001
Peak levels of NO2, PM10 and PM2.5 (ppvb), DA and Non-DA, 2001.
<table>
<tr><th></th><th>CBS</th><th>UBG</th><th>DWN</th></tr>
<tr><td>NO_2 peak (non-DA)</td><td>45</td><td>20</td><td>20</td></tr>
<tr><td>NO_2 peak (DA)</td><td>9</td><td>13</td><td>11</td></tr>
<tr><td>PM_{10} peak (non-DA)</td><td>150</td><td>-</td><td>-</td></tr>
<tr><td>PM_{10} peak (DA)</td><td>95</td><td>-</td><td>-</td></tr>
<tr><td>$PM_{2.5}$ peak (non-DA)</td><td>65</td><td>-</td><td>-</td></tr>
<tr><td>$PM_{2.5}$ peak (DA)</td><td>48</td><td>-</td><td>-</td></tr>
</table>

Analysis
There were decreases in levels of NO_2 across all sampling sites.</td>
<td>impact of the DA on ambient concentrations due to variations in meteorological conditions.

Limitations identified by the review team
All industrial / commercial activities also ceased along with use of vehicles. Not clear if reduction down to limitation of vehicle or industrial / commercial emissions.</td>
</tr>
<tr>
<td>Full citation
Levy, Jonathan I., Baxter, Lisa K., Clougherty, Jane E., The air quality impacts of road closures associated with the 2004 Democratic National Convention in Boston, Environmental health : a global access science source, 5, 16, 2006

Quality score
+</td>
<td>Participant characteristics
Sampling sites were chosen to represent hypothesised impacts from the DNC on changes in traffic volume.
Four categories of sites were identified:
1. Sites with hypothesized concentration decreases: Proximate to a</td>
<td>Intervention / Comparison
The DNC was held from 26-29 July 2004. Approximately 40 miles of road were closed for some period of time (generally from 4pm to midnight) around the city during that period, including a major highway and multiple surface and feeder roads.</td>
<td>Outcomes

NO_2 concentrations (ppb) during DNC and non-DNC weeks, stratified by a priori traffic classification
<table>
<tr><th>Catagory</th><th>Median concentration and range, DNC</th><th>Median concentration and range, non-DNC*</th><th>Median concentration ratio (DNC/non-DNC) and range</th></tr>
<tr><td>1 – Hypothesized decrease (n = 7)</td><td>7 (3-16)</td><td>10 (6-20)</td><td>0.58 (0.27-2.0)</td></tr>
<tr><td>2 – Hypothesized increase (n = 9)</td><td>14 (7-19)</td><td>12 (3-15)</td><td>1.15 (0.51-1.88)</td></tr>
</table></td>
<td>Limitations identified by the author
The study was undertaken over a relatively small number of days therefore the findings could be explained by general meteorological trends that correspond with the sampling periods. Athough there were no obvious patterns in local meteorological or air</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>Study type
Before and after

Aim of the study
To determine the impact of road closures on air quality within a city during a Democratic National Convention (DNC).

Location and setting
Boston, USA

Length of study
7 days

Source of funding
Sampling was supported by funds from Environmental Defense</td>
<td>closed-down road or highway but not proximate to an identified alternate route.
2. Sites with hypothesized concentration increases: Proximate to an identified alternate route but not a closed down road.
3. Sites with no change hypothesized: Geographically isolated from the road closures or alternate routes.
4. Site with unclear impacts <i>a priori</i>: Site with multiple countervailing influences. For example, measurements taken near a highway without road closures could have concentration decreases if overall traffic were reduced, but could have concentration increases if these roads were used as alternate routes to downtown Boston.

Inclusion criteria
Sampling sites were selected as close to the roadway in question as was feasible, with no major obstructions between the roadway and the monitor.</td>
<td>NO_2 concentrations were measured at 40 sampling sites with passive filter badges. Badges were swapped weekly at each sampling site, providing samples corresponding to the week before, during and after the DNC. Duplicate samples and field blanks were used at 10% of sites, selected by random number generation.</td>
<td><table>
<tr><td>3 – Hypothesized no change (n = 11)</td><td>11 (6-19)</td><td>12 (7-17)</td><td>0.88 (0.82-1.23)</td></tr>
<tr><td>4 – Unclear impacts a priori (n = 7)</td><td>7 (6-9)</td><td>12 (4-18)</td><td>0.70 (0.38-2.4)</td></tr>
</table>
*Average of concentration the week before and after the DNC

Analysis
Those sites for which traffic was anticipated to decrease had a median concentration ratio of 0.58, versus median ratios of 0.88 for "no change" sites and 1.15 for sites where traffic was expected to increase. There was evidence that mean concentrations during the DNC were lower at the sites with hypothesized concentration decreases or unclear a priori impacts (p=0.10 and p=0.05, respectively), higher at the sites with hypothesized concentration increases (p=0.13), and unchanged at the sites with no hypothesized change (p=0.79).</td>
<td>pollution data, significant rainfall immediately prior to the DNC could have influenced concentration trends in following days.
However, wind speeds and ozone concentrations were both lower during the DNC, factors that would tend to increase near-source traffic contributions to NO_2 so the true impact of the road closures may have been greater than the increments estimated.
Some of the road closures were not strictly enforced during all time periods.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr><td></td><td>**Exclusion criteria**
Not reported</td><td></td><td></td><td></td></tr>
<tr>
<td>**Full citation**
Owen, B., Air quality impacts of speed-restriction zones for road traffic, Science of the total environment, 340, 13-22, 2005

Quality score
-

Study type
Controlled before and after study

Aim of the study
To investigate the air quality impact of six 20mph zones implemented in the North West of England.

Location and setting
Six towns in the North West of England

Length of study

Source of funding
The study was funded by the then UK Department of the Environment, Transport and the Regions (DETR) now Department for Transport (DfT).

Ref Id
570549</td>
<td>**Number of participants**

Participant characteristics
Monitoring was undertaken in 3 locations in six 20 mph zones of approximately 0.5x0.5 km in area.

Inclusion criteria
Monitoring locations were selected using the following criteria:
- Each site should be located at a similar distance from the kerbside to ensure consistency between the sites allowing comparison between the site data
- The sites should be as close to the kerbside as possible (preferably between 1 and 5 metres from kerb edge of the road) to enable concentration changes arising from emissions on the affected roads to be identified
- The samplers should be positioned at a similar height above ground level again to ensure consistency between the sites
The samplers should not</td>
<td>**Intervention / Comparison**
Ambient concentrations of NO_2 were measured before and after the implementation of six 20 mph zones. The zones had road traffic signs and road humps to decrease vehicle speeds. NO_2 was also measured at one site outside each 20mph zone as a control.

At 2 of the zones (Warrington and Sefton), NO_2 was monitored for consecutive 1-month periods for as long as possible before the implementation of the 20 mph zone (5 and 9 months) and for 12 months after implementation. For the remaining 4 zones, single monthly averages were measured for a period before implementation, 3 months after and 12 months after implementation.

The mean values before and after implementation of the zones were calculated. Temporal trends over and above those resulting from meteorological conditions were identified where</td>
<td>**Outcomes**

Site 1: Sefton (monitoring undertaken for 5 months prior to and 12 months after implementation) - Average site NO_2 before and implementation of the 20mph zone
<table>
<tr><th></th><th>Road 1</th><th>Road 2</th><th>Road 3</th><th>Control site 4</th></tr>
<tr><td>*Before*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nov 98 - Mar 99</td><td>47.2</td><td>44.4</td><td>44.4</td><td>43.8</td></tr>
<tr><td>Number of samples</td><td>9</td><td>10</td><td>11</td><td>6</td></tr>
<tr><td>Standard deviation</td><td>9.9</td><td>10.3</td><td>12.0</td><td>5.1</td></tr>
<tr><td>*After*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Apr 99 - Mar 00</td><td>45.1</td><td>40.0</td><td>38.7</td><td>41.1</td></tr>
<tr><td>Number of samples</td><td>28</td><td>30</td><td>24</td><td>28</td></tr>
<tr><td>Standard deviation</td><td>8.6</td><td>7.6</td><td>9.5</td><td>9.7</td></tr>
<tr><td>% change in average concentrations</td><td>-4</td><td>-10</td><td>-13</td><td>-6</td></tr>
<tr><td>*After (winter only)*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nov 99 - Mar 00</td><td>45.0</td><td>40.9</td><td>34.3</td><td>37.6</td></tr>
<tr><td>Number of samples</td><td>14</td><td>13</td><td>9</td><td>12</td></tr>
</table>

Site 2: Warrington (monitoring undertaken for 9 months prior to and 12 months after implementation) - Average site NO_2 before and implementation of the 20mph zone
<table>
<tr><th></th><th>Road 1</th><th>Road 2</th><th>Road 3</th><th>Control site 4</th></tr>
<tr><td>*Before*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Jan 98 - Sept 98</td><td>42.7</td><td>43.8</td><td>42.3</td><td>42.3</td></tr>
<tr><td>Number of samples</td><td>27</td><td>25</td><td>30</td><td>28</td></tr>
<tr><td>Standard deviation</td><td>11.2</td><td>12.4</td><td>11.6</td><td>11.8</td></tr>
<tr><td>*After*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Oct 98 - Sept 99</td><td>46.9</td><td>44.4</td><td>43.2</td><td>42.7</td></tr>
<tr><td>Number of samples</td><td>29</td><td>33</td><td>34</td><td>28</td></tr>
<tr><td>Standard deviation</td><td>11.0</td><td>8.6</td><td>9.5</td><td>8.6</td></tr>
<tr><td>% change in average concentrations</td><td>10</td><td>1</td><td>2</td><td>1</td></tr>
</table></td>
<td>**Limitations identified by the author**
The spatial extent of each of the 20mph zones was fairly small and therefore total measured concentrations were influenced strongly by background concentrations. However , the proximity of the monitoring site locations to the affected roads (less than 5m from the kerbside) allowed any significant changes in emissions and therefore concentrations to be identified.

Limitations identified by the review team
No discussion regarding the effect of confounding factors on emissions. No measures of significance reported.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr><td></td><td>be located adjacent to or in the proximity of any significant point source of pollution.</td><td>relevant.</td><td>

Monthly average NO_2 values at 20mph zones before and after implementation (μg m^{3})

<table>
<tr><td>20 mph zone</td><td>Sites</td><td>Before</td><td>After 3 months</td><td>After 12 months</td></tr>
<tr><td>Darwen</td><td>Road 1</td><td>41.9</td><td>23 (-44%)</td><td>42 (0%)</td></tr>
<tr><td></td><td>Road 2</td><td>45.7</td><td>21 (-54%)</td><td>30 (-35%)</td></tr>
<tr><td></td><td>Road 3</td><td>38.1</td><td>21 (-47%)</td><td>42 (10%)</td></tr>
<tr><td></td><td>Control</td><td>36.2</td><td>19 (-47%)</td><td>40 (12%)</td></tr>
<tr><td>Oldham</td><td>Road 1</td><td>28.6</td><td>27 (-7%)</td><td>34 (20%)</td></tr>
<tr><td></td><td>Road 2</td><td>32.4</td><td>32 (0%)</td><td>36 (12%)</td></tr>
<tr><td></td><td>Road 3</td><td>28.6</td><td>30 (7%)</td><td>29 (0%)</td></tr>
<tr><td></td><td>Control</td><td>34.3</td><td>27 (-28%)</td><td>38 (6%)</td></tr>
<tr><td>Salford</td><td>Road 1</td><td>51.4</td><td>63 (23%)</td><td>44 (-15%)</td></tr>
<tr><td></td><td>Road 2</td><td>51.4</td><td>65 (68%)</td><td>30 (-20%)</td></tr>
<tr><td></td><td>Road 3</td><td>38.1</td><td>63 (65%)</td><td>65 (70%)</td></tr>
<tr><td></td><td>Control</td><td>34.3</td><td>59 (74%)</td><td>32 (-3%)</td></tr>
<tr><td>Trafford</td><td>Road 1</td><td>57.1</td><td>57 (0%)</td><td>50 (-13%)</td></tr>
<tr><td></td><td>Road 2</td><td>49.5</td><td>53 (8%)</td><td>55 (12%)</td></tr>
<tr><td></td><td>Road 3</td><td>53.3</td><td>51 (-4%)</td><td>51 (-4%)</td></tr>
<tr><td></td><td>Control</td><td>47.6</td><td>40 (-16%)</td><td>46 (-4%)</td></tr>
</table>

Analysis

Sefton: There were reductions of NO_2 concentrations of between 4 and 13% at all the Sefton monitoring sites (including the control site) after implementation of the 20 mph zone. The decreases were within the range of uncertainty for the measurements of this pollutant using diffusion tubes (±25%).

Warrington: Concentrations of NO_2 increased after implementation of the 20 mph zone. There was a 10% increase at one of the monitoring sites but only small increases of 1 or 2% at the other sites. As above, these figures are within the range of uncertainty for the measurements of this pollutant using diffusion tubes (±25%). Overall, the changes at the 2 sites indicate that there was no significant change in the concentration of NO2 measured before and after implementation of the 20mph zone.

The measurements of NO_2 at various sites within the 20mph zones studies generally followed similar patterns to the concentrations recorded at the control sites outside the zone. The changes observed between before and after implementation of the 20mph zones were generally within the error of margin of the measurement techniques used and therefore not significant. Where changes could be deemed to be significant, the

</td><td></td></tr>
</table>

Study details	Population	Intervention / Comparator	Results	Notes
			authors stated that these were likely to be as a result of the prevailing meteorological conditions during the monitoring survey periods (although no further details of these provided).	
Full citation Quiros, D. C., Zhang, Q., Choi, W., He, M., Paulson, S. E., Winer, A. M., Wang, R., Zhu, Y., Air quality impacts of a scheduled 36-h closure of a major highway, Atmospheric Environment, 67, 404-414, 2013 **Quality score** + **Study type** Before and after **Aim of the study** To evaluate the effect of a major road closure on air pollutant levels. **Location and setting** Los Angeles, USA **Length of study** 2 days **Source of funding** California Air Resources Board, Contract No.09-357	**Participant characteristics** Freeway (10 lanes) with approximately 380,000 vehicles/day **Inclusion criteria** Not reported **Exclusion criteria** Not reported	**Intervention / Comparison** In 2011, a section of a major freeway was closed for 36 hours from midnight Friday until midday on the Sunday. Fixed site measurements of particle number concentration (PNC), $PM_{2.5}$ and black carbon were conducted between 10:00 and 20:00 for 3 consecutive Friday-Sunday periods, pre, during and post-closure. Fixed-site measurements were conducted upwind and downwind of the freeway for all campaign days.	**Outcomes** Downwind PNCs were 31%, 83% and 63% lower for closure conditions for Friday, Saturday and Sunday respectively, than the average non-closure increases in PNCs. Upwind $PM_{2.5}$ for the closure period was 55%, 39%, and 49% lower for the closure Friday through Sunday, respectively, compared with the post-closure period. Downwind black carbon was 25%, 62% and 65% lower for the closure Friday through Sunday, respectively, compared with the post-closure period. Closure of the freeway led to basin-wide freeway traffic reductions. These extended as far north as Fresno (380km) and as far south as Oceanside (160km). Ambient monitoring of PM2.5 indicated decreases of between 18 and 36%, indicating that the closure led to regional traffic reduction contributing to an overall average 25% reduction in PM2.5 observed in multiple locations. **Analysis** There was a decrease in PNCs, $PM_{2.5}$ and black carbon concentrations after the intervention was applied.	**Limitations identified by the author** Measurements for the closure period were only included for 2 days and not 3 days as the other periods. **Limitations identified by the review team** Freeway was not completely closed in both directions, some access southbound was allowed (1 lane) after a particular junction.

Question 5: Are traffic management systems and signal coordination interventions effective at reducing the health impact of, or people's exposure to, traffic-related air pollution? Modelling studies

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Method of analysis</th><th>Model results</th><th>Notes</th></tr>
<tr>
<td>**Full citation**
Ahn, Kyoungho, Rakha, Hesham, A Field Evaluation Case Study of the Environmental and Energy Impacts of Traffic Calming, Transportation Research: Part D: Transport and Environment, 14, 411-24, 2009

Quality score
-

Aim of the study
To quantify the energy and environmental impact of a selection of traffic calming measures using a combination of second-by-second floating-car global positioning system data and microscopic energy and emission models.

Source of data
Natural driving data collected in Northern Virginia at 3 sites

Location and setting
Key Boulevard,</td>
<td>**Number of participants**
Key Boulevard: 2 male, 2 female drivers in 2 vehicles (1 passenger car, 1 SUV) completing 80 runs.
31st Street and Broadview Drive: 2 drivers completing 20 trips before and 20 after installation of traffic calming.

Participant description
Not given.

Inclusion criteria
Valid round trip in either direction.

Exclusion criteria
Trips containing unexpected delay or stop were not included as a valid trip.</td>
<td>**Intervention / Comparison**
Key Boulevard: no control junction vs stop control vs traffic circle vs traffic humps
31st Street and Broadview: BA installation of traffic calming features</td>
<td>**Type of model**
Driving cycles developed using second-by-second natural GPS data, aggregated from multiple drivers across at least 20 repetitions along each study corridor.
Fuel consumption and emission rates predicted using the VT-Micro model with second-by-second speed and acceleration as variable inputs.</td>
<td>**Outcomes**

Fuel consumption and NOx emissions with various junction controls as % of base case
<table>
<tr><th colspan="3">Fuel consumption (% of base case)</th><th colspan="3">NOx emissions (% of base case</th></tr>
<tr><th>Stop</th><th>Circle</th><th>Hump</th><th>Stop</th><th>Circle</th><th>Hump</th></tr>
<tr><td>114%</td><td>34%</td><td>53%</td><td>264%</td><td>56%</td><td>110%</td></tr>
</table>

Emission of NOx (g/100m) by vehicle type on traffic calmed streets
<table>
<tr><th rowspan="2">Vehicle type</th><th colspan="2">31st Street (speed lumps)</th><th colspan="2">Broadview Drive (speed bumps)</th></tr>
<tr><th>Before</th><th>After</th><th>Before</th><th>After</th></tr>
<tr><td>**Normal ORNL**</td><td>24.3</td><td>48.2</td><td>16.6</td><td>19.8</td></tr>
<tr><td>**Light Duty LDV3**</td><td>8.3</td><td>9.3</td><td>5.0</td><td>5.3</td></tr>
<tr><td>**High emitter HE4**</td><td>199.6</td><td>205.7</td><td>132.3</td><td>130.0</td></tr>
</table>

Analysis
While traffic calming measures reduce vehicle speeds on neighbouring streets and may contribute to enhanced road safety these measures can result in significantly higher fuel consumption and emission rates when drivers accelerate aggressively.</td>
<td>**Limitations identified by the author**
Data collected during weekend days to minimize interactions with other vehicles or pedestrians.
Limited number of drivers and vehicles employed for data collection.
Results are site specific.

Other comments
Engineering measures used and legislation may vary from conditions in the UK so limiting applicability.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Method of analysis</th><th>Model results</th><th>Notes</th></tr>
<tr><td>Arlington; 31st Street, Arlington, Broadview Drive, Ashburn

Length of study
N/A

Source of funding
Not given.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Full citation
Boulter, P. G., Hickman-Davis, J. M., Latham, S., Davison, P., Whiteman, P., The impacts of traffic calming measures on vehicle exhaust emissions, 96, 2001

Quality score
-

Aim of the study
To investigate the effects of a range of traffic calming measures on the exhaust emissions of passenger cars.

Source of data
Field measurements of two-way 24 hr traffic flows, vehicle speed profile determined using LIDAR, traffic composition from LIDAR video record.</td><td>Number of participants
N/A

Participant description
N/A

Inclusion criteria
N/A

Exclusion criteria
N/A</td><td>Intervention / Comparison
B/A installation of schemes (75mm high flat top road hump, 80mm high round top road hump, 100mm high raised junction, 1.9m wide speed cushion, 1.7m wide speed cushion, combined pinch point and speed cushion,). Chicane, build out, mini-roundabout also included but suitable site not identified in time for before measurements. Estimates of traffic speed used as 'before' data for these interventions.</td><td>Type of model
Speed profiles developed using LIDAR data before and after calming and used to estimate drive cycles. Emissions from 12 petrol and 3 diesel vehicles were measured when following the driving cycles using average and continuous N Ox emissions for different classes of vehicle.</td><td>Outcomes

Percentage increases in mean emissions due to traffic calming
<table>
<tr><th rowspan="2">Vehicle category</th><th colspan="4">Percentage increase in mean emissions</th></tr>
<tr><th>Hydrocarbons</th><th>NOx</th><th>CO_2</th><th>PM</th></tr>
<tr><td>Petrol non-catalyst</td><td>50%*</td><td>1%</td><td>20%*</td><td>N/A</td></tr>
<tr><td>Petrol catalyst</td><td>54%*</td><td>8%</td><td>26%*</td><td>N/A</td></tr>
<tr><td>Diesel</td><td>48%*</td><td>28%*</td><td>26%*</td><td>30%*</td></tr>
</table>

Percentage change in emissions of NOx by class of vehicle
<table>
<tr><th>Traffic calming measure</th><th colspan="6">Petrol non-catalyst cars</th><th colspan="6">Petrol catalyst cars</th><th colspan="3">Diesel cars</th></tr>
<tr><td></td><td colspan="2">Small</td><td colspan="2">Medium</td><td colspan="2">Large</td><td colspan="2">Small</td><td colspan="2">Medium</td><td colspan="2">Large</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>A</td><td>+27</td><td>+7</td><td>+22</td><td>+43</td><td>+13</td><td>+13</td><td>0</td><td>+94</td><td>+80</td><td>+69</td><td>+9</td><td>+159</td><td>+31</td><td>+41</td><td>+44</td></tr>
<tr><td>B</td><td>+10</td><td>+2</td><td>+16</td><td>+22</td><td>+6</td><td>-14</td><td>+8</td><td>-14</td><td>+37</td><td>+48</td><td>+17</td><td>0</td><td>+24</td><td>+53</td><td>+45</td></tr>
<tr><td>C</td><td>+19</td><td>+19</td><td>+22</td><td>+23</td><td>+15</td><td>+18</td><td>+63</td><td></td><td>+27</td><td>+3</td><td>+25</td><td>+138</td><td>+22</td><td>+28</td><td>+30</td></tr>
<tr><td>D</td><td>+3</td><td>+1</td><td>+1</td><td>+6</td><td>+11</td><td>+8</td><td>+22</td><td>-43</td><td>+19</td><td>+68</td><td>+8</td><td>+58</td><td>+16</td><td>+25</td><td>+25</td></tr>
<tr><td>E</td><td>+15</td><td>-4</td><td>+7</td><td>+2</td><td>-1</td><td>-15</td><td>-23</td><td>-38</td><td>-37</td><td>+35</td><td>-57</td><td>-21</td><td>+39</td><td>+41</td><td>+37</td></tr>
<tr><td>F</td><td>-16</td><td>-30</td><td>-21</td><td>-22</td><td>-6</td><td>-16</td><td>+4</td><td>-25</td><td>-70</td><td>+57</td><td>-10</td><td>-27</td><td>+17</td><td>+27</td><td>+17</td></tr>
<tr><td>G</td><td>+10</td><td>-17</td><td>-20</td><td>-1</td><td>-8</td><td>-16</td><td>-7</td><td>-34</td><td>+5</td><td>-9</td><td>+20</td><td>-7</td><td>+13</td><td>+26</td><td>+21</td></tr>
<tr><td>H</td><td>+10</td><td>-3</td><td>+13</td><td>+16</td><td>-4</td><td>-3</td><td>+6</td><td>-16</td><td>+84</td><td>-16</td><td>-12</td><td>+42</td><td>+26</td><td>+38</td><td>+52</td></tr>
<tr><td>I</td><td>-22</td><td>-31</td><td>-21</td><td>-3</td><td>-22</td><td>-20</td><td>-38</td><td>-2</td><td>-52</td><td>+44</td><td>-36</td><td>+7</td><td>+1</td><td>+30</td><td>+30</td></tr>
</table>

Analysis
The overall effect was an increase in emissions from traffic calming schemes, particularly</td><td>Limitations identified by the author
Single sites for each measure
'Before' data not available for 3 measures
Same vehicles not used for all emission testing

Limitations identified by the review team

Other comments
The study was carried out in 2001 with vehicles going back to 1991. This will not reflect the current make up of the UK vehicle fleet.</td></tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Method of analysis</th><th>Model results</th><th>Notes</th></tr>
<tr>
<td>Location and setting
Various settings across the UK

Length of study
N/A

Source of funding
Department of the Environment, Transport and the Regions.</td>
<td></td>
<td></td>
<td></td>
<td>for diesel cars. However the impact of a scheme varies with vehicle type and pollutant so general trends are difficult to discern. The authors suggest that for petrol cars schemes G (build out) and I (1.9m wide speed cushions) tended to have a relatively low impact, whereas A (flat topped hump) and B (round topped hump) tended to have a high overall impact. For diesel cars, schemes D (pinch point/speed cushion) and scheme G (build-out) tended to have a lower impact than the other schemes, and scheme A (flat-top hump) tended to have a high impact. There was a general but weak trend for the impacts of the traffic calming measures incorporating vertical deflections (i.e. road humps and raised junction) to be higher than those incorporating horizontal deflections or a requirement to give way. This may be related to the fact that in the second instance the measures were studied in isolation, whereas the vertical deflections were repeated at fairly regular intervals.</td>
<td></td>
</tr>
<tr>
<td>Full citation
Ghafghazi, Golnaz, Hatzopoulou, Marianne, Simulating the Environmental Effects of Isolated and Area-Wide Traffic Calming Schemes Using Traffic Simulation and Microscopic Emission Modeling, Transportation, 41, 633-49, 2014

Quality score
+

Aim of the study
Development of a microscopic traffic simulation and emission modelling system which aims at quantifying the effects of different types of traffic calming measures on vehicle emissions both at a</td>
<td>Number of participants
N/A

Participant description
N/A

Inclusion criteria
N/A

Exclusion criteria
N/A</td>
<td>Intervention / Comparison
Modelled results with and without traffic calming measures. 8 scenarios (+base case) examined:
speed bumps (speed reduction to 5 kph) on 1 of 3 major residential streets (scenarios 1-3)
network 30 kph limit
speed bumps on all 3 major residential streets
speed humps on all 3 major residential streets (speed reduction to 25-30 kph)
speed humps on all 3 major residential streets + network wide 30 kph speed limit
speed bumps on all 3 major residential streets</td>
<td>Type of model
Traffic microsimulation (VISSIM). Emissions estimated using US MOVES model.</td>
<td>Outcomes
Emission of pollutants with various traffic calming scenarios
<table>
<tr><th></th><th>CO2 (tons)</th><th>NOx (Kg)</th><th>VKT</th><th>CO2 (g/VKT)</th><th>NOx (g/VKT)</th></tr>
<tr><td>Base case</td><td>2.8</td><td>3.57</td><td>9751</td><td>287.41</td><td>0.336</td></tr>
<tr><td>Scenario 1</td><td>2.82</td><td>3.60</td><td>9690</td><td>291.51</td><td>0.372</td></tr>
<tr><td>Scenario 2</td><td>2.84</td><td>3.62</td><td>9744</td><td>291.33</td><td>0.372</td></tr>
<tr><td>Scenario 3</td><td>2.85</td><td>3.61</td><td>9739</td><td>292.36</td><td>0.371</td></tr>
<tr><td>Scenario 4</td><td>2.84</td><td>3.53</td><td>9738</td><td>291.45</td><td>0.362</td></tr>
<tr><td>Scenario 5</td><td>2.98</td><td>3.78</td><td>9775</td><td>305.14</td><td>0.387</td></tr>
<tr><td>Scenario 6</td><td>2.83</td><td>3.62</td><td>9733</td><td>291.04</td><td>0.372</td></tr>
<tr><td>Scenario 7</td><td>2.84</td><td>3.53</td><td>9683</td><td>293.39</td><td>0.364</td></tr>
<tr><td>Scenario 8</td><td>3.02</td><td>3.74</td><td>9691</td><td>311.18</td><td>0.386</td></tr>
</table>

Analysis
Isolated measures (scenarios 1 – 3) increase CO2 emissions along the corridor itself by 15-81% compared to the base case, while the rest of the network does not experience a significant change. Total distance travelled decreases but emission rate increase due to changes in driving speeds and changes in speed. Area wide calming increases emissions on the treated road and also worsens emissions across the network. Speed bumps (that cause a greater slowing) increase emissions more than speed humps, particularly on the treated sections.</td>
<td>Limitations identified by the author
Validation of vehicle instantaneous speeds and emission rates was not possible within the scope of the current study.
Basic emission rates determined using US vehicles not Montreal specific.
Limited traffic calming measures only could be simulated.
Emissions only were estimated, street-level air quality is not assessed.

Other comments
The paper reports base case emissions of NOx as 3.57 (as in table above). Using the data on VKT and NOx g/VKT gives a figure of 3.28kg, lower than total emissions from any of the scenarios considered.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Method of analysis</th><th>Model results</th><th>Notes</th></tr>
<tr><td>link-level and at a network-level

Source of data
Traffic simulation of trips using VISSIM; estimation of emissions based on links produced by MOVES model.

Location and setting
Sub area of Plateau-Mont-Royal Borough, Montreal, Canada.

Length of study
N/A

Source of funding
Not given</td><td></td><td>+ 30 kph speed limit.</td><td></td><td></td><td></td></tr>
<tr><td>Full citation
Ghafghazi, Golnaz, Hatzopoulou, Marianne, Simulating the Air Quality Impacts of Traffic Calming Schemes in a Dense Urban Neighborhood, Transportation Research: Part D: Transport and Environment, 35, 11-22, 2015
Quality score
+

Aim of the study
To illustrate the importance of conducting air</td><td>Number of participants
N/A

Participant description
N/A

Inclusion criteria
N/A

Exclusion criteria
N/A</td><td>Intervention / Comparison
Modelled results with and without traffic calming measures. 7 scenarios (+base case) examined:
speed bumps (speed reduction to 5 kph) on 1 of 3 major residential streets (scenarios 1-3)
speed bumps on all 3 major residential streets
speed humps on all 3 major residential streets (speed reduction to 25-30 kph)</td><td>Type of model
Traffic microsimulation (VISSIM). Emissions estimated using US MOVES model. Dispersion modelling using Danish Operational Street Pollution Model (OSPM).</td><td>Outcomes

Percentage change in NOx emissions and NO2 concentrations under each scenario (compared to the base case) for selected corridors
<table>
<tr><th></th><th>Sc1,2,3: speed bumps on roads</th><th></th><th>Sc4: network wide speed bumps</th><th></th><th>Sc5: network wide speed humps</th><th></th><th>Sc6: network wide speed humps and speed limit</th><th></th><th>Sc7: network wide speed bumps and speed limit</th><th></th></tr>
<tr><td></td><td>%NO2 conc</td><td>%NOx emission</td><td>%NO2 conc</td><td>%NOx emission</td><td>%NO2 conc</td><td>%NOx emission</td><td>%NO2 conc</td><td>%NOx emission</td><td>%NO2 conc</td><td>%NOx emission</td></tr>
<tr><td>Chambord 1</td><td>7.6</td><td>44.3</td><td>7.5</td><td>43.0</td><td>1.8</td><td>7.7</td><td>1.8</td><td>5.3</td><td>7.6</td><td>42.5</td></tr>
<tr><td>Chambord 2</td><td>6.6</td><td>46.1</td><td>7.3</td><td>55.0</td><td>1.7</td><td>9.2</td><td>0.1*</td><td>-5.0</td><td>7.1</td><td>54.7</td></tr>
<tr><td>Chambord 3</td><td>7.0</td><td>50.3</td><td>7.3</td><td>54.0</td><td>2.9</td><td>23.0</td><td>0.4*</td><td>-2.7</td><td>5.5</td><td>35.3</td></tr>
</table></td><td>Limitations identified by the author

Limitations identified by the review team

Other comments</td></tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Method of analysis</th><th>Model results</th><th>Notes</th></tr>
<tr>
<td>dispersion modelling rather than inferring potential air quality effects from changes in emissions solely and to quantify the effects of different types of traffic calming measures on near-road air quality.

Source of data
Traffic simulation of trips using VISSIM; estimation of emissions based on links produced by MOVES model; modelling of concentrations of air pollutants along each corridor following traffic calming.

Location and setting
Sub area of Plateau-Mont-Royal Borough, Montreal, Canada.

Length of study
N/A

Source of funding
Not given</td>
<td></td>
<td>speed humps on all 3 major residential streets + network wide 30 kph speed limit speed bumps on all 3 major residential streets + 30 kph speed limit.</td>
<td></td>
<td>
<table>
<tr><td>Chambord 4</td><td>8.7</td><td>75.9</td><td>8.0</td><td>68.0</td><td>2.4</td><td>24.0</td><td>0.7</td><td>5.8</td><td>8.0</td><td>68.3</td></tr>
<tr><td>Chambord 5</td><td>3.7</td><td>19.4</td><td>4.2</td><td>22.9</td><td>0.6</td><td>1.2</td><td>-1.9</td><td>-23.7</td><td>3.1</td><td>13.2</td></tr>
<tr><td>Chambord 6</td><td>7.3</td><td>135.8</td><td>7.9</td><td>161.2</td><td>2.3</td><td>47.0</td><td>1.1</td><td>17.5</td><td>7.0</td><td>132.4</td></tr>
<tr><td>Garnier 1</td><td>5.1</td><td>104.6</td><td>5.4</td><td>110.4</td><td>2.2</td><td>47.5</td><td>-0.1</td><td>-3.6</td><td>3.5</td><td>60.4</td></tr>
<tr><td>Garnier 2</td><td>5.2</td><td>112.1</td><td>5.3</td><td>116.5</td><td>2.7</td><td>58.8</td><td>1.5</td><td>27.9</td><td>4.6</td><td>95.8</td></tr>
<tr><td>Garnier 3</td><td>3.3</td><td>23.2</td><td>3.0</td><td>18.6</td><td>-1.1</td><td>-12.7</td><td>-2.0</td><td>-22.5</td><td>2.6</td><td>13.5</td></tr>
<tr><td>Garnier 4</td><td>5.6</td><td>29.3</td><td>6.3</td><td>35.8</td><td>1.3</td><td>6.1</td><td>-1.7</td><td>-16.8</td><td>4.6</td><td>20.4</td></tr>
<tr><td>Garnier 5</td><td>4.1</td><td>20.5</td><td>4.3</td><td>21.5</td><td>1.5</td><td>7.5</td><td>-1.8</td><td>-16.9</td><td>4.1</td><td>15.3</td></tr>
<tr><td>Garnier 6</td><td>9.7</td><td>92.4</td><td>9.3</td><td>82.8</td><td>3.0</td><td>27.9</td><td>1.3</td><td>5.6</td><td>9.1</td><td>81.1</td></tr>
<tr><td>Marquette 1</td><td>5.6</td><td>66.4</td><td>6.5</td><td>78.9</td><td>2.1</td><td>22.6</td><td>-0.8</td><td>-16.3</td><td>4.7</td><td>50.8</td></tr>
<tr><td>Marquette 2</td><td>7.0</td><td>104.9</td><td>6.6</td><td>98.2</td><td>3.4</td><td>58.8</td><td>1.1</td><td>11.9</td><td>5.2</td><td>72.2</td></tr>
<tr><td>Marquette 3</td><td>6.6</td><td>48.3</td><td>6.9</td><td>51.9</td><td>0.2*</td><td>-2.9</td><td>-0.2</td><td>-6.9</td><td>6.9</td><td>53.6</td></tr>
<tr><td>Marquette 4</td><td>6.5</td><td>41.8</td><td>6.8</td><td>45.6</td><td>2.7</td><td>19.0</td><td>-1.7</td><td>-15.7</td><td>5.1</td><td>28.4</td></tr>
<tr><td>Marquette 5</td><td>7.3</td><td>55.2</td><td>7.6</td><td>58.9</td><td>3.7</td><td>29.3</td><td>-0.9</td><td>-7.3</td><td>9.9</td><td>62.5</td></tr>
<tr><td>Marquette 6</td><td>9.3</td><td>81.8</td><td>8.8</td><td>77.6</td><td>3.3</td><td>30.1</td><td>0.8*</td><td>1.3</td><td>8.0</td><td>65.0</td></tr>
</table>
* Not statistically significant (at 5%)

Analysis
Traffic calming using speed bumps lead to higher NOx concentrations than speed humps. The largest increase in NOx compared to the base-case scenario was 9.9%. Under scenarios 5 and 6 (where there were area wide speed humps) some segments saw a fall in NOx concentrations (less than 2%). As changes in drive cycles with humps were not as substantial as those with speed bumps the resulting increase in emissions is not significant enough to offset the reduction in traffic volumes on the corridors with changes. The authors note that traffic calming measures have a smaller effect on NO2 concentrations than on NOx emissions. Average NO2 levels increased by between 0.1% and 10% with respect to the base- case scenario while NOx emissions varied by between 5% and 160%. Speed bumps (resulting in higher speed reductions) produced higher increases than speed humps.</td>
<td></td>
</tr>
</table>

Question 6: Are zoning interventions effective and cost effective at reducing the health impact of, or people’s exposure to, traffic-related air pollution?

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>Full citation
Atkinson, R. W., Barratt, B., Armstrong, B., Anderson, H. R., Beevers, S. D., Mudway, I. S., Green, D., Derwent, R. G., Wilkinson, P., Tonne, C., Kelly, F. J., The impact of the congestion charging scheme on ambient air pollution concentrations in London, Atmospheric Environment, 43, 5493-5500, 2009

Quality score
-

Study type
Controlled before and after

Aim of the study
To investigate the effects of a congestion charge scheme (CCS) on pollutant concentrations within the congestion charging zone (CCZ) and on the area surrounding the charging zone.

Location and setting
London, UK

Source of funding
Health Effects Institute through research agreement</td>
<td>Number of participants
Pollutants were measured at both roadside and background monitoring sites across Greater London, including sites: within the CCZ; in the area surrounding the zone (boundary zone); and in a control area 8 km or more from the CCZ but within Greater London.
Roadside monitoring sites:
• CCZ - 1 site
• Boundary zone - 8 sites
• Control zone - 16 sites
Background monitoring sites:
• CCZ - 3 sites
• Boundary zone - 8 sites
• Control zone - 7 sites</td>
<td>Intervention / Comparison
Introduction of a congestion charging scheme in central London. The scheme operates via a punitive charge on 4-wheeled vehicles entering the charging zone during the period Monday-Friday between 07:00 to 18:00. Daily pollutant concentrations were measured at roadside and background monitoring sites. Changes in pollution concentrations within the CCZ were compared to changes at monitors unlikely to be affected by the CCS (the control area) and in the boundary zone between the two for the 2-year period before and the 2-year period after the introduction of the CCS.</td>
<td>Outcomes

Mean concentrations of pollutants at roadside monitoring sites 2 years before and 2 years after the introduction of the CCS
<table>
<tr><th>Monitoring station</th><th>Distance in km from centre of the CCZ</th><th colspan="3">NO_2 (ppb)</th><th colspan="3">PM_{10} ($\mu g\ m^{-3}$)</th></tr>
<tr><td></td><td></td><td>Pre</td><td>Post</td><td>%</td><td>Pre</td><td>Post</td><td>%</td></tr>
<tr><td><i>CCZ</i></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Site 1</td><td>1.0</td><td>42.1</td><td>43.0</td><td>2.1</td><td>41.0</td><td>43.3</td><td>5.6</td></tr>
<tr><td><i>Boundary zone</i></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Site 1</td><td>3.0</td><td>50.0</td><td>68.0</td><td>36.0</td><td>51.9</td><td>52.9</td><td>2.0</td></tr>
<tr><td>Site 2</td><td>3.5</td><td>54.8</td><td>58.8</td><td>7.4</td><td></td><td></td><td></td></tr>
<tr><td>Site 3</td><td>4.3</td><td>50.8</td><td>58.1</td><td>14.3</td><td></td><td></td><td></td></tr>
<tr><td>Site 4</td><td>4.6</td><td>45.4</td><td>48.2</td><td>6.0</td><td>43.5</td><td>41.8</td><td>-3.6</td></tr>
<tr><td>Site 5</td><td>4.8</td><td>36.3</td><td>37.0</td><td>1.8</td><td></td><td></td><td></td></tr>
<tr><td>Site 6</td><td>5.4</td><td>37.7</td><td>35.2</td><td>-6.6</td><td></td><td></td><td></td></tr>
<tr><td>Site 7</td><td>5.7</td><td></td><td></td><td></td><td>36.5</td><td>41.3</td><td>12.9</td></tr>
<tr><td>Site 8</td><td>7.9</td><td>27.5</td><td>27.8</td><td>0.9</td><td>28.8</td><td>31.7</td><td>10.2</td></tr>
<tr><td><i>Control zone (average of 16 sites)</i></td><td>8 km+</td><td></td><td></td><td>3.7</td><td></td><td></td><td>2.5</td></tr>
</table>

Mean concentrations of pollutants at background monitoring sites 2 years before and 2 years after the introduction of the CCS
<table>
<tr><th>Monitoring station</th><th>Distance in km from centre of the CCZ</th><th colspan="3">NO_2 (ppb)</th><th colspan="3">PM_{10} ($\mu g\ m^{-3}$)</th></tr>
<tr><td></td><td></td><td>Pre</td><td>Post</td><td>%</td><td>Pre</td><td>Post</td><td>%</td></tr>
<tr><td><i>CCZ</i></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Site 1</td><td>1.5</td><td>29.0</td><td>32.7</td><td>12.8</td><td>35.6</td><td>30.1</td><td>-15.4</td></tr>
<tr><td>Site 2</td><td>1.5</td><td>30.5</td><td>30.8</td><td>1.0</td><td></td><td></td><td></td></tr>
<tr><td>Site 3</td><td>1.9</td><td>25.1</td><td>26.9</td><td>7.2</td><td></td><td></td><td></td></tr>
<tr><td><i>Boundary zone</i></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td>
<td>Limitations identified by the author
There was only 1 roadside monitor within the CCS zone therefore it was not possible to identify any relative changes in pollution concentrations associated with the introduction of the scheme.
Causal attribution of small changes in air pollution concentrations to the CCS is not appropriate since the scheme was introduced concurrently with other traffic and emissions interventions (including a package of changes in traffic management and in the public vehicle fleet) which might have had a more concentrated effect in central London.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>RFA04-1/04</td>
<td></td>
<td></td>
<td>
<table>
<tr><td>Site 1</td><td>2.5</td><td>27.7</td><td>27.6</td><td>-0.2</td><td></td><td></td><td></td></tr>
<tr><td>Site 2</td><td>3.6</td><td>24.3</td><td>24.8</td><td>2.0</td><td>27.3</td><td>30.1</td><td>10.2</td></tr>
<tr><td>Site 3</td><td>4.8</td><td>24.5</td><td>23.2</td><td>-5.4</td><td></td><td></td><td></td></tr>
<tr><td>Site 4</td><td>6.0</td><td>26.8</td><td>29.0</td><td>8.4</td><td></td><td></td><td></td></tr>
<tr><td>Site 5</td><td>6.7</td><td>22.7</td><td>19.8</td><td>-13.1</td><td>25.9</td><td>28.6</td><td>10.4</td></tr>
<tr><td>Site 6</td><td>6.9</td><td>20.1</td><td>20.7</td><td>2.8</td><td>25.5</td><td>26.4</td><td>3.6</td></tr>
<tr><td>Site 7</td><td>7.0</td><td>25.7</td><td>26.7</td><td>3.6</td><td></td><td></td><td></td></tr>
<tr><td>Site 8</td><td>7.8</td><td>29.4</td><td>33.0</td><td>12.2</td><td></td><td></td><td></td></tr>
<tr><td><i>Control zone (average of 7 sites)</i></td><td>8 km+</td><td></td><td></td><td>0.2</td><td></td><td></td><td>-0.8</td></tr>
</table>

Analysis
There were comparable increases in roadside concentrations of NO_2 and PM_{10} at the CCZ monitoring site and at monitoring stations in the control zone after the implementation of the intervention.
Background concentrations of PM_{10} within the CCZ fell whilst concentrations of NO_2 increased. There was a small average increase of NO_2 in the control zone and a small decrease in PM_{10}.
PM10 levels at the only monitoring site inside the congestion charging zone fell by 15.4% (from 35.6 – 30.1 μg/m3) while the average fall at the 3 control sites was 0.8%.
For NO_2 there was no consistent pattern in the direction and size of the percentage changes measured at both roadside and background stations in the boundary zone.
</td>
<td></td>
</tr>
<tr>
<td>Full citation
Boogaard, H., Janssen, N. A. H., Fischer, P. H., Kos, G. P. A., Weijers, E. P., Cassee, F. R., van der Zee, S. C., de Hartog, J. J., Meliefste, K., Wang, M., Brunekreef, B., Hoek, G., Impact of low emission zones and local traffic policies on ambient air pollution concentrations, Science of the total environment, 435-436, 132-140, 2012

Quality score</td>
<td>Participant characteristics
Measurements were taken at 8 major streets and 5 urban background locations (one in each of five cities in the Netherlands) located within a LEZ. An additional urban background location was selected as a reference location to adjust for temporal variation (not in the LEZ). A further 4 suburban background locations were included as control locations (1</td>
<td>Intervention / Comparison
From July 2007 to October 2008 a LEZ was gradually implemented in several Dutch cities. The policy was directed at forbidding 'old' trucks to enter LEZ in the inner city. Initially, only EURO-0 and EURO-I trucks were forbidden, whereas EURO-II and EURO-III trucks were only allowed if they were retrofitted. EURO-II and EURO-III trucks were largely tolerated until</td>
<td>Outcomes
<i>Average concentrations of different pollutants ($\mu g/m^{3)}$ before (2008) and after (2010) introduction of the LEZ policy</i>
<table>
<tr><th>Location</th><th colspan="3">PM_{10}</th><th colspan="3">$PM_{2.5}$</th><th colspan="3">NO_2</th></tr>
<tr><th></th><th>Pre</th><th>Post</th><th>Absolute difference</th><th>Pre</th><th>Post</th><th>Absolute difference</th><th>Pre</th><th>Post</th><th>Absolute difference</th></tr>
<tr><td>Street</td><td>28.1</td><td>25.0*</td><td>-3.1</td><td>16.8</td><td>11.8*</td><td>-5.1**</td><td>47.2</td><td>45.7</td><td>-1.5</td></tr>
<tr><td>Urban Background</td><td>25.1</td><td>21.2*</td><td>-4.0</td><td>14.7</td><td>10.8</td><td>-3.9</td><td>32.0</td><td>28.6</td><td>-3.4</td></tr>
<tr><td>Suburban Background</td><td>22.4</td><td>19.0</td><td>-3.3</td><td>13.8</td><td>11.1*</td><td>-2.7</td><td>25.8</td><td>21.2*</td><td>-4.5</td></tr>
</table>
* denotes significant difference pre and post at the 0.05 level
** denotes significant difference pre and post between street and matching suburban location at the 0.05 level.

Average particle number concentrations (p/cm^3) before (2008) and after (2010) introduction of the LEZ policy</td>
<td>Limitations identified by the author
None reported

Limitations identified by the review team
The LEZ was implemented prior to 2008 (when the before measurements were taken) in 3 out of 5 of the cities studies. Enforcement with fines for drivers entering the LEZ illegally was only tightened up in 2010 which could bias the results of the study.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>+

Study type
Controlled before and after

Aim of the study
To evaluate the impact of the implementation of a low emission zone (LEZ) directed at heavy duty vehicles on air pollution concentrations.

Location and setting
5 cities in the Netherlands

Source of funding
Ministry of Infrastructure and the Environment with additional funding from the Province of Noord-Brabant.</td>
<td>suburban location was used for 2 nearby cities). The suburban background locations were in villages (~30,000 inhabitants) near the selected cities (10–30km). In addition PNCs were measured at 4 of these locations (2 urban streets, 2 suburban background locations).</td>
<td>2008/2009. In addition, since 2010 all EURO-II trucks were forbidden, and EURO-III trucks were only allowed if retrofitted with particulate filters and if not older than 8 years.
Measurements of air pollutants conducted simultaneously at street, urban background and suburban background locations over 2 6-month periods in 2008, before the implementation of the intervention, and in 2010, after implementation. Measurements were adjusted for temporal variation using data from the central reference location.</td>
<td>
<table>
<tr><th>Location</th><th colspan="3">PNC Total</th></tr>
<tr><th></th><th>Pre</th><th>Post</th><th>Absolute difference</th></tr>
<tr><td>Street location 1</td><td>16,191</td><td>17,579</td><td>1388</td></tr>
<tr><td>Street location 2</td><td>10,443</td><td>16,410*</td><td>5967</td></tr>
<tr><td>Suburban Background 1</td><td>6839</td><td>7263</td><td>424</td></tr>
<tr><td>Suburban Background 2</td><td>6611</td><td>9941*</td><td>3330</td></tr>
</table>
*denotes significant difference pre and post at the 0.05 level

Analysis
Average concentrations of PM_{10}, $PM_{2.5}$ and NO_2 decreased after the intervention was implemented in all 3 locations.
There were significant decreases in PM_{10} at both street and urban background level, in $PM_{2.5}$ at street and suburban background level, and in NO_2 at suburban background level.
There was a significant reduction in $PM_{2.5}$ concentrations at the urban streets level than at the matching suburban background locations.
PNCs increased at all locations after the intervention.</td>
<td>Apart from LEZ, other traffic policies measures were introduced in the same period as well. Wind speed was significantly lower in the 2010 than in the 2008 sampling periods.</td>
</tr>
<tr>
<td>Full citation
Dijkema, M. B. A., van der Zee, S. C., Brunekreef, B., van Strien, R. T., Air quality effects of an urban highway speed limit reduction, Atmospheric Environment, 42, 9098-9105, 2008

Quality score
+

Study type
Controlled before and after study

Aim of the study
To assess whether</td>
<td>Participant characteristics
6 lane highway with an adjacent monitoring station. 92,000 vehicles / day travel along the western section, 140,000 pass the southern section (no intervention).</td>
<td>Intervention / Comparison
In November 2005 the maximum speed for the western part of a Dutch highway was limited from 100 to 80 kph. Daily mean concentrations in the year after the intervention were compared to daily mean concentrations in the year before (excluding August).</td>
<td>Outcomes

Concentrations of air pollutants due to traffic (roadside minus daily mean background) in Amsterdam, one year prior to the intervention
<table>
<tr><th></th><th></th><th>N</th><th>Mean</th><th>Range (min-max)</th></tr>
<tr><td rowspan="2">PM_{10} ($\mu g\ m^{-3}$)</td><td>Highway West</td><td>331</td><td>8.18</td><td>(-2.40 - 23.95)</td></tr>
<tr><td>Highway South</td><td>330</td><td>3.67</td><td>(-9.60 - 13.20)</td></tr>
</table>
Concentrations of air pollutants due to traffic (roadside minus daily mean background) in Amsterdam, one year post intervention
<table>
<tr><th></th><th></th><th>N</th><th>Mean</th><th>Range (min-max)</th></tr>
<tr><td rowspan="2">PM_{10} ($\mu g\ m^{-3}$)</td><td>Highway West</td><td>327</td><td>5.75</td><td>(-6.00 - 24.30)</td></tr>
<tr><td>Highway South</td><td>316</td><td>2.63</td><td>(-25.55 - 13.60)</td></tr>
</table>
Speed limit intervention effects on PM_{10} (concentration at roadside minus urban background)
<table>
<tr><th></th><th>With intervention</th><th>Without intervention</th></tr>
</table></td>
<td>Limitations identified by the author
Two weeks before the intervention was implemented a noise barrier was installed along the western highway section
The two highway sections are not exactly the same. While the western section has adjoining apartment buildings, the southern section is located in a relatively open area next to a river. Also, the embankment elevation of the two sections is different, 4.8 m at</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>a policy to lower the maximum speed
limit from 100 to 80 kph reduces traffic related air pollution.

Location and setting
An urban highway, the Netherlands

Source of funding
Not reported</td>
<td></td>
<td></td>
<td>
<table>
<tr><td rowspan="2">PM_{10} ($\mu g\ m^{-3}$)</td><td>Change</td><td>95% CI</td><td>Change</td><td>95% CI</td></tr>
<tr><td>-2.34*</td><td>-3.13 to -1.55</td><td>-0.63</td><td>-1.41 - 0.16</td></tr>
</table>
* $p<0.05$

Analysis
The concentration of PM_{10} was significantly reduced when the intervention was applied.</td>
<td>the western section, 7.6 m at the southern.

Limitations identified by the review team
92,000 vehicles / day travel along the western section (intervention site) compared to 140,000 which pass the southern section (control site). This could bias the results of the study.</td>
</tr>
<tr>
<td>Full citation
Fensterer, V., Kuchenhoff, H., Maier, V., Wichmann, H. E., Breitner, S., Peters, A., Gu, J., Cyrys, J., Evaluation of the impact of low emission zone and heavy traffic ban in Munich (Germany) on the reduction of PM10 in ambient air, International Journal of Environmental Research and Public Health, 11, 5094-5112, 2014

Quality score
+

Study type
Controlled before and after

Aim of the study
To examine the impact of a low emission zone and transit bans for heavy-duty vehicles
on PM10 concentrations.

Location and setting</td>
<td>Participant characteristics
PM_{10} data was collected at 3 monitoring sites within the LEZ:

1. An urban background site (Lothstrasse - measurement height: 4 m over ground)
2. A street site (Prinzregentenstrasse - measurement height: 2.9 m over ground; distance to road: 3 m; 39,000 vehicles/day in 2007–2010).
3. A regional background site in the outskirts of the city and outside the LEZ (Johanneskirchen - measurement height: 4 m over ground; distance to road: 5 m).</td>
<td>Intervention / Comparison
The impact of 2 measures on PM_{10} levels were assessed:

1. A ban on heavy-duty vehicles (>3.5 tons) travelling through the city area (From 1st Feb 2008)
2. The introduction of a low emission zone (LEZ). From 1st Oct 2008 all vehicles with Euro 1 (or worse) were no longer allowed to enter and drive within the LEZ area. From 1st October 2010 all vehicles
with Euro 2 were excluded</td>
<td>Outcomes

Means of the unadjusted PM_{10} concentrations at the 3 stations with (Oct 2008-Sept 2010) and without (Feb 2006-Jan 2008) LEZ measures and the corresponding percentage differences separated by season (Summer: April–September; Winter: October–March)
<table>
<tr><th>Measurement station</th><th>Season</th><th colspan="3">Without measures</th><th colspan="3">With measures</th><th>% difference</th></tr>
<tr><td></td><td></td><td>n</td><td>PM_{10}</td><td>SD</td><td>n</td><td>PM_{10}</td><td>SD</td><td></td></tr>
<tr><td>Prinzregentenstrasse</td><td>Summer</td><td>8200</td><td>27.2</td><td>14.3</td><td>6535</td><td>23.4</td><td>14.5</td><td>-14.0</td></tr>
<tr><td></td><td>Winter</td><td>8562</td><td>30.8</td><td>21.6</td><td>8676</td><td>30.2</td><td>23.6</td><td>-1.9</td></tr>
<tr><td>Lothstrasse</td><td>Summer</td><td>8769</td><td>21.3</td><td>12.9</td><td>8730</td><td>20.8</td><td>15.3</td><td>-2.3</td></tr>
<tr><td></td><td>Winter</td><td>8520</td><td>28.3</td><td>23.6</td><td>8687</td><td>27.6</td><td>22.0</td><td>-2.5</td></tr>
<tr><td>Johanneskirchen</td><td>Summer</td><td>8765</td><td>19.3</td><td>12.2</td><td>8768</td><td>18.9</td><td>12.3</td><td>-2.1</td></tr>
<tr><td></td><td>Winter</td><td>8451</td><td>24.3</td><td>21.6</td><td>8686</td><td>24.5</td><td>20.8</td><td>0.8</td></tr>
</table>

Change of PM_{10} concentration in period 2 (Oct 2008-Sept 2010) when compared to period 1 (Feb 2006-Jan 2008) at Prinzregentenstrasse and Lothstrasse (adjusted for exposure at the reference station, wind direction, day of the week, time of the day and public holidays)
<table>
<tr><th>Measurement station</th><th colspan="3">Summer</th><th colspan="3">Winter</th><th colspan="3">Winter/summer combined</th></tr>
<tr><td></td><td>Effect</td><td>CI</td><td>p-value</td><td>Effect</td><td>CI</td><td>p-value</td><td>Effect</td><td>CI</td><td>p-value</td></tr>
<tr><td>Prinzregentenstrasse</td><td>-19.63%</td><td>(-22.75% to -16.52%)</td><td><0.001</td><td>-6.80%</td><td>(-10.14 to-3.47%)</td><td><0.001</td><td>-13%</td><td>Not given</td><td><0.001</td></tr>
<tr><td>Lothstrasse</td><td>-5.73%</td><td>(-7.71% to -3.74%)</td><td><0.001</td><td>-3.18%</td><td>(-5.24% to -1.11%)</td><td>0.003</td><td>-4.5%</td><td>Not given</td><td><0.001</td></tr>
</table>
</td>
<td>Limitations identified by the author
None reported

Limitations identified by the review team
PM10 measurements at 1 of the monitoring sites were only available until 31 June 2010 because the station was closed. This could have biased the results.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>Munich, Germany

Length of study
Period 1: February 2006–January 2008
Period 2: October 2008–September 2010

Source of funding
US Environmental Protection Agency STAR center grant RD 832415 (EPA Particulate Matter Centre, Rochester, NY., USA) and EU ERA-ENVHEALTH grant agreement No. 219337.</td>
<td></td>
<td>from the LEZ.

PM_{10} concentrations were compared prior to the implementation of any air quality measures (1 February 2006 - 31 January 2008) with PM_{10} concentrations measured after the measures became effective (1 October 2008 - 30 September 2010). The period from 1 February 2008 to 30 September 2008 was excluded from the analysis as only a truck transit ban was effective. In addition, PM_{10} values on 1 January were excluded from the analysis for each year due to the traditional New Year's Eve fireworks.</td>
<td>**Analysis**
The unadjusted mean PM_{10} concentrations were higher in the winter season and lower in the summer season. At both urban stations (Prinzregentenstrasse and Lothstrasse) there was a decrease of PM_{10} in period 2 compared to period 1. There was also a reduction in PM_{10} at the reference station in Johanneskirchen.
The comparison of the PM_{10} concentrations (adjusted for exposure at the reference station, wind direction, day of the week, time of the day and public holidays) showed a statistically significant reduction in PM_{10} concentrations at both sites. The reduction was higher at the street site (Prinzregentenstrasse) compared with the urban background site (Lothstrasse).</td>
<td></td>
</tr>
<tr>
<td>**Full citation**
Invernizzi, G., Ruprecht, A., Mazza, R., De Marco, C., Mocnik, G., Sioutas, C., Westerdahl, D., Measurement of black carbon concentration as an indicator of air quality benefits of traffic restriction policies within the ecopass zone in Milan, Italy, Atmospheric Environment, 45, 3522-3527, 2011

Quality score
-</td>
<td>**Number of participants**
3 main roads consisting of 3 segments:
1. Pedestrianised zone
2. Congestion charge zone (Ecopass) which requires diesel vehicles (prior EURO4 tier and vehicles conforming to EURO4 tier without a particulate filter) to pay a toll to enter restricted zone between 08:00a.m. and 08:00p.m.
3. No traffic restriction zone</td>
<td>**Intervention / Comparison**
The study was carried out on 3 different days. Black carbon concentrations were measured at fixed monitoring stations located on 3 radial roads connecting the outskirts to the city centre, each road with 3 segments:
1. An outer zone with no traffic restrictions
2. An intermediate zone subject to a congestion traffic charge ("Ecopass") where a ticket is</td>
<td>**Outcomes**

Mean (SD) black carbon concentrations ($\mu g/m^3$) measured at the different traffic zones on the different campaign days
<table>
<tr><th>Site locations</th><th>July 19th</th><th>July 21st</th><th>July 29th</th></tr>
<tr><td>Pedestrian zone</td><td>1.6 (0.4)</td><td>2.0 (0.5)</td><td>1.5 (0.5)</td></tr>
<tr><td>Ecopass zone</td><td>3.1 (1.7)</td><td>2.8 (1.4)</td><td>2.6 (1.9)</td></tr>
<tr><td>No restriction zone</td><td>6.3 (2.9)</td><td>5.2 (2.3)</td><td>3.3 (1.9)</td></tr>
</table>
$p<0.0001$ between the three different zones for each day, except for no-restriction vs Ecopass zone on July 29th ($p=0.006$).

24 hour mean PM_{10} concentrations ($\mu g/m^{-3}$) measured at the different traffic zones on the different campaign days
<table>
<tr><th>Site locations</th><th>July 19th</th><th>July 21st</th><th>July 29th</th></tr>
<tr><td>Ecopass zone</td><td>20</td><td>34</td><td>18</td></tr>
<tr><td>No restriction zone</td><td>20</td><td>32</td><td>16</td></tr>
</table></td>
<td>**Limitations identified by the author**
The study was conducted over a limited number of campaign days in one season only. Measurements were interrupted at 2 sampling sites on 1 day due to a period of rain which required the instruments to be covered.

Limitations identified by the review team
No clear rationale as to why sample days chosen</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>**Study type**
Controlled study

Aim of the study
To demonstrate differences in local urban air quality among 3 zones with different traffic intensity.

Location and setting
Milan, Italy

Length of study
3 days

Source of funding
SIMG, Società Italiana di Medicina Generale (Italian College GPs).</td>
<td></td>
<td>required to enter for cars equipped with engines prior to Euro 4 standard
3. A pedestrian zone (no cars admitted)

24 hour PM$_{10}$ concentrations were obtained from 1 site located inside the Ecopass zone and 1 site in the no traffic restriction zone.</td>
<td>**Analysis**
The pedestrian zone consistently showed lower black carbon concentrations on all 3 campaign days compared to the Ecopass zone, while the sites in the Ecopass zones showed reduced black carbon concentrations as compared to the unrestricted traffic zones.
There were no significant differences in PM$_{10}$ between the 2 zones (Ecopass and no-restriction) on any of the campaign days.</td>
<td></td>
</tr>
<tr>
<td>**Full citation**
Jones, A. M., Harrison, R. M., Barratt, B., Fuller, G., A large reduction in airborne particle number concentrations at the time of the introduction of " sulphur free" diesel and the London Low Emission Zone, Atmospheric Environment, 50, 129-138, 2012

Quality score
-

Study type
Controlled before and after

Aim of the study
To evaluate the effect of the introduction of a Low Emission Zone (LEZ) on</td>
<td>**Participant characteristics**
The measurement of particle number concentrations was taken from 3 monitoring sites:
1. Roadside site (Marylebone Road) located on a major highway in street canyon in central London, with a traffic volume of around 80,000 vehicles per day.
2. Urban background site (North Kensington) is within the grounds of a school in a residential suburb of London approximately 4 km from the roadside</td>
<td>**Intervention / Comparison**
Introduction of the London LEZ. The LEZ was enforced for heavy goods vehicles (HGVs) greater than 12 tonnes from February 2008, and for other goods vehicles, buses and coaches greater than 3.5 tonnes from July 2008. The LEZ applies to vehicles using diesel and biodiesel fuels, and requires HGVs to comply with the EURO III emission standard for particulate matter, or better. The EURO III standard for HGVs does not require the fitting of a particle trap.
Airborne particle concentrations were</td>
<td>**Outcomes**

Particle number concentrations in the periods before and after implementation of the LEZ
<table>
<tr><th></th><th colspan="3">Before: Oct 2005 - Sept 2007</th><th colspan="3">After: Feb 2008 - Jan 2009</th><th rowspan="2">Ratio After/Before</th></tr>
<tr><th>Site</th><th>Mean (cm^{-3})</th><th>Std err (cm^{-3})</th><th>% data</th><th>Mean (c m^{-3})</th><th>Std err (cm^{-3})</th><th>% data</th></tr>
<tr><td>Marylebone Road</td><td>83,400</td><td>404</td><td>80.6</td><td>34,400</td><td>266</td><td>59.2</td><td>0.41</td></tr>
<tr><td>North Kensington</td><td>23,400</td><td>109</td><td>89.3</td><td>14,300</td><td>102</td><td>87.9</td><td>0.61</td></tr>
<tr><td>Birmingham centre</td><td>18,600</td><td>121</td><td>78.5</td><td>12,900</td><td>105</td><td>71.8</td><td>0.70</td></tr>
</table>

PM$_{10}$ (µg m^{-3}) concentrations in the periods before and after implementation of the LEZ
<table>
<tr><th></th><th colspan="3">Before: Oct 2005 - Sept 2007</th><th colspan="3">After: Feb 2008 - Jan 2009</th><th rowspan="2">Ratio After/Before</th></tr>
<tr><th>Site</th><th>Mean</th><th>Std err</th><th>% data</th><th>Mean</th><th>Std err</th><th>% data</th></tr>
<tr><td>Marylebone</td><td>34.8</td><td>0.1</td><td>97.4</td><td>35.8</td><td>0.2</td><td>95.4</td><td>1.03</td></tr>
</table>
</td>
<td>**Limitations identified by the author**
None reported

Limitations identified by the review team
Other changes occurred at a similar time to the LEZ implementation which could have affected the results.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>airborne particle concentrations.

Location and setting
London, UK

Source of funding
DEFRA</td>
<td>site.
3. Urban centre site (Birmingham centre). Located adjacent to a car park and pedestrianised plaza. The main highway route through central Birmingham enters a naturally ventilated tunnel 200m to the south east of the site, where there is also a road junction above the tunnel portal, while the main railway station in Birmingham is located 400m to the east south east.</td>
<td>compared for the period October 2005 to September 2007 (pre-LEZ) and February 2008 to January 2009 (post LEZ implementation).</td>
<td>
<table>
<tr><td>Road</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>North Kensington</td><td>19.4</td><td>0.1</td><td>98.9</td><td>18.1</td><td>0.1</td><td>98.7</td><td>0.93</td></tr>
</table>
Analysis
There were reductions in particle number concentrations at all three sites: roadside site (59%), urban background site (39%) and urban centre site (30%).
In contrast, there was a slight decrease in PM_{10} concentrations at the urban background site (7%) but a slight increase in concentrations at the roadside site.
</td>
<td></td>
</tr>
<tr>
<td>Full citation
Kelly, Frank, Anderson, H. Ross, Armstrong, Ben, Atkinson, Richard, Barratt, Ben, Beevers, Sean, Derwent, Dick, Green, David, Mudway, Ian, Wilkinson, Paul, H. E. I. Health Review Committee, The impact of the congestion charging scheme on air quality in London. Part 1. Emissions modeling and analysis of air pollution measurements, Research report (Health Effects Institute), 5-71, 2011

Quality score
-</td>
<td>Participant characteristics
Not reported

Inclusion criteria
Not reported

Exclusion criteria
Not reported</td>
<td>Intervention / Comparison
Implementation of a Congestion Charge Scheme (CCS) in London.
Measurements of pollutants were taken from monitors sited to record roadside or urban or suburban background air pollutants across London. These data were used to calculate geometric mean concentrations of these pollutants for the 2 years before and 2 year after after the implementation of the CCS. Changes over time at the monitors in Congestion Charge Zone (CCZ) were</td>
<td>
Outcomes

Differences in Geometric Mean (GM) Concentrations Before and After CCS Introduction at Roadside Locations Within and Outside the CCZ for Weekdays
<table>
<tr><th></th><th colspan="3">NO_2 (ppb)</th><th colspan="3">PM_{10} ($\mu g/m^3$)</th></tr>
<tr><th>Monitoring Site</th><th>GM Pre</th><th>GE Post</th><th>% Change</th><th>GM Pre</th><th>GE Post</th><th>% Change</th></tr>
<tr><td><i>Within the CCZ</i></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Site 1</td><td>42.1</td><td>43.0</td><td>1.9</td><td>41.0</td><td>43.3</td><td>5.7</td></tr>
<tr><td><i>Outside the Zone</i></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Site 1</td><td>29.0</td><td>29.9</td><td>2.9</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Site 2</td><td>31.2</td><td>31.5</td><td>1.1</td><td>32.6</td><td>32.3</td><td>-1.0</td></tr>
<tr><td>Site 3</td><td>28.0</td><td>27.5</td><td>-1.6</td><td>32.8</td><td>29.2</td><td>-11.0</td></tr>
<tr><td>Site 4</td><td>30.6</td><td>33.6</td><td>9.8</td><td>31.8</td><td>33.3</td><td>4.7</td></tr>
<tr><td>Site 5</td><td>23.5</td><td>23.2</td><td>-1.2</td><td>28.3</td><td>28.9</td><td>2.4</td></tr>
<tr><td>Site 6</td><td>30.7</td><td>31.4</td><td>2.4</td><td>38.9</td><td>40.7</td><td>4.5</td></tr>
<tr><td>Site 7</td><td>27.2</td><td>25.6</td><td>-5.9</td><td>29.9</td><td>31.7</td><td>5.9</td></tr>
<tr><td>Site 8</td><td>32.4</td><td>27.8</td><td>-14.4</td><td>29.5</td><td>29.1</td><td>-1.2</td></tr>
<tr><td>Site 9</td><td>24.8</td><td>24.9</td><td>0.6</td><td>28.1</td><td>27.7</td><td>-1.2</td></tr>
</table>
</td>
<td>Limitations identified by the author
Continuous monitoring of pollutant levels for the specific purpose of observing changes caused by the introduction of the CCS had not been established before it was implemented.
Measurements were taken at existing sites that did not precisely fit the needs of this study.
There was a lack of data from monitoring sites within the CCZ, particularly for roadside locations. Only a single monitor provided roadside data for NO_2</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>Study type
Controlled before and after

Aim of the study
To evaluate the impact of the London Congestion Charge Scheme on air quality.

Location and setting
London, UK

Length of study
4 years (February 2001 to February 2005)

Source of funding
Not reported</td>
<td></td>
<td>compared with changes at similar classes of monitoring sites in a control area over 8 km from the centre of the CCZ.</td>
<td>
<table>
<tr><td>Site 10</td><td>24.3</td><td>26.4</td><td>8.3</td><td>28.9</td><td>31.5</td><td>9.2</td></tr>
<tr><td>Site 11</td><td>33.4</td><td>48.4</td><td>44.7</td><td>35.6</td><td>35.5</td><td>-0.5</td></tr>
<tr><td>Site 12</td><td>24.7</td><td>23.5</td><td>-4.6</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Site 13</td><td>23.1</td><td>22.9</td><td>-0.9</td><td>27.7</td><td>27.9</td><td>0.9</td></tr>
<tr><td>Site 14</td><td>25.4</td><td>27.7</td><td>9.0</td><td>28.7</td><td>31.2</td><td>8.8</td></tr>
<tr><td>Site 15</td><td>23.2</td><td>23.1</td><td>-0.7</td><td>26.3</td><td>28.0</td><td>6.1</td></tr>
<tr><td>Site 16</td><td>34.4</td><td>42.6</td><td>24.0</td><td>29.3</td><td>33.7</td><td>15.0</td></tr>
</table>

Differences in GM Concentrations Before and After CCS Introduction at Background Locations Within and Outside the Zone for Weekdays
<table>
<tr><th></th><th colspan="3">NO_2 (ppb)</th><th colspan="3">PM_{10} ($\mu g/m^3$)</th></tr>
<tr><th>Monitoring Site</th><th>GM Pre</th><th>GE Post</th><th>% Change</th><th>GM Pre</th><th>GE Post</th><th>% Change</th></tr>
<tr><td><i>Within the CCZ</i></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Site 1</td><td>29.0</td><td>32.7</td><td>12.7</td><td>35.6</td><td>30.1</td><td>-15.4</td></tr>
<tr><td>Site 2</td><td>30.5</td><td>30.8</td><td>0.9</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Site 3</td><td>25.1</td><td>26.9</td><td>7.4</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td><i>Outside the Zone</i></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Site 1</td><td>17.9</td><td>18.1</td><td>0.6</td><td>23.1</td><td>24.0</td><td>3.7</td></tr>
<tr><td>Site 2</td><td>19.6</td><td>21.6</td><td>10.3</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Site 3</td><td>16.7</td><td>15.8</td><td>-5.0</td><td>23.3</td><td>21.5</td><td>-8.0</td></tr>
<tr><td>Site 4</td><td>13.0</td><td>13.5</td><td>3.4</td><td>21.6</td><td>20.8</td><td>-3.9</td></tr>
<tr><td>Site 5</td><td>28.8</td><td>28.2</td><td>-1.8</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Site 6</td><td>19.8</td><td>20.0</td><td>1.1</td><td>25.0</td><td>26.3</td><td>5.2</td></tr>
<tr><td>Site 7</td><td>19.8</td><td>18.8</td><td>-4.9</td><td>24.5</td><td>24.3</td><td>-0.5</td></tr>
</table>

Analysis

NO_2
No_2 levels in the CCZ at roadside sites increased by 1.9% after the introduction of the CCS. In comparison, No_2 levels in the control area decreased at 7 out of 16 roadside sites (14.4% to 0.7%) and increased at 9 out of 16 sites (0.6% to 44.7%).
There were increases in No_2 levels at the background sites in the CCZ of 0.9%, 7.4%, and 12.7% compared with falls of between 1.8% and 5.0% at 3 of 7 control background sites and rises of between 0.6% and 10.3% at 4 of 7 control background sites.

PM_{10}
</td>
<td>and PM_{10}.
The urban background PM_{10} sampling site had building works close to the analyzer which corresponded with increased PM_{10} measurements.
The CCS was introduced at a time when other traffic and emission interventions were being implemented which may have had an effect on changes in air quality.

Other comments
Monitoring data were not included for those sites and pollutant species that failed to meet the 75% capture-
rate requirement.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr><td></td><td></td><td></td><td>PM_{10} concentrations in the CCZ at roadside sites increased by 5.7% after the introduction of the CCS. In comparison, PM_{10} concentrations in the control area decreased at 5 of the 14 roadside sites (0.5% to 11.0%) and increased at 9 of the 14 sites (0.9% to 15.4%).
There was a decrease of 15.4% in PM_{10} concentrations in the background CCZ monitoring site compared with decreases of 0.5% to 8.0% at 3 of 5 control background sites and rises of 3.7% and 5.2% at 2 of 5 control background sites.
Overall, there was no evidence to suggest that concentrations of pollutants measured at roadside locations within the CCZ fell after the introduction of the CCS relative to the control area during the hours the CCS operated. There was evidence to suggest that background concentrations of NO_2 had increased slightly within the CCZ compared with the control area after the CCS was implemented. In addition, there was evidence to suggest that background concentrations of PM_{10} fell within the CCZ compared with the control area, although this was based on the results from a single site.</td><td></td></tr>
<tr><td>Full citation
Keuken, M. P., Jonkers, S., Wilmink, I. R., Wesseling, J., Reduced NOx and PM10 emissions on urban motorways in The Netherlands by 80km/h speed management, Science of the total environment, 408, 2517-2526, 2010

Quality score
-

Study type
Before and After

Aim of the study
To evaluate the effect of a speed restriction on NO_2 and PM_{10} emissions.

Location and setting
Motorways in urban areas in Rotterdam and Amsterdam, Netherlands

Length of study</td>
<td>Participant characteristics
6 or more lanes, flat terrain, traffic of more than 140,000 vehicles per 24 hrs, and a typical fleet composition of 5% trucks, 5% vans and 90% private cars.
PM_{10} instruments were located in a range of 40 to 80 m from the motorways. The two locations on both sides of a motorway were not symmetrical in terms of transport of pollution from the motorway to the monitoring instruments. Therefore, depending on wind directions, one location was selected as background station and the other as exposed location.
NO_2 samplers were located at a distance of 5 to 15 m from the motorway along the length of approximately</td>
<td>Intervention / Comparison
Implementation of a 80 km/h zone in urban areas on sections of motorway. In Rotterdam, the speed limit was 100 km/h; in Amsterdam it was already 80 km/h, but without strict enforcement.
Air quality monitoring was performed from April until November 2005 (before implementation of the speed management zones) and from November 2005 until November 2006 (after implementation).</td>
<td>Outcomes

Average NO_2 contributions and standard deviation(µg/m3) at exposed monitoring locations on both sides of the motorway
<table>
<tr><th></th><th colspan="3">Without intervention</th><th colspan="3">With intervention</th></tr>
<tr><th></th><th>NO_2 concentration (µg/m^3)</th><th>Number of samples (n)</th><th>Std dev</th><th>NO_2 concentration (µg/m^3)</th><th>Number of samples (n)</th><th>Std dev</th></tr>
<tr><td>Amsterdam</td><td>9.2</td><td>17</td><td>4.9</td><td>8.2</td><td>20</td><td>3.2</td></tr>
<tr><td>Rotterdam</td><td>39.3</td><td>20</td><td>13.3</td><td>35.9</td><td>24</td><td>7.0</td></tr>
</table>
Emission reductions (%) of PM10 and NOx at the 80km/h zones
<table>
<tr><td></td><td></td><td colspan="2">Emission reduction (%)</td></tr>
<tr><td></td><td></td><td>Air quality monitoring</td><td>Traffic dynamics</td></tr>
<tr><td>Amsterdam</td><td>PM10</td><td>-</td><td>20</td></tr>
<tr><td></td><td>NOx</td><td>32</td><td>24</td></tr>
<tr><td>Rotterdam</td><td>PM10</td><td>8</td><td>16</td></tr>
<tr><td></td><td>NOx</td><td>30</td><td>21</td></tr>
</table>

Analysis
There was a decrease in NO_2 concentration at both sites after the intervention was implemented. However, this difference can not directly be attributed to the effect of the 80 km/h zone, as meteorological conditions and traffic intensity may differ between the periods without and with the 80 km/h zone.</td>
<td>Limitations identified by the author
Distance of NO_2 samplers were 12-15 m from the road edge in Amsterdam. Distance at Rotterdam was 5 m
Traffic intensity was larger at Rotterdam (170,000 - 164,000 vehicles / day) than Amsterdam (111,000 - 108,000 vehicles / day)
Due to construction activities near the monitoring location in Amsterdam, the PM_{10} results were not reliable</td></tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>Not reported

Source of funding
Ministry of Traffic, Public Transport and Water Management in The Netherlands</td>
<td>100 m per 80 km/h zone.

Inclusion criteria
PM$_{10}$: In order to measure the motorway emissions at the downwind locations, only hours were selected during which wind directions were perpendicular to the motorways within ±30° and wind speeds exceeded 1 m/s. In view of the monitoring uncertainty the data analysis included only measured contributions larger than 2 µg PM$_{10}$/m^3.

Exclusion criteria
Not reported</td>
<td></td>
<td>Based on air quality monitoring in combination with dispersion modelling, the study showed an average 8% reduction in PM10 and 30% reduction in NOx emissions following speed management. These results are not significant for PM10, which the authors attribute to the relatively low ratio of traffic contribution and the background concentration. Results from traffic dynamics and emission models showed reductions of around 15-20% for PM10 and 20-25% for NOx for Amsterdam and Rotterdam.</td>
<td></td>
</tr>
<tr>
<td>**Full citation**
Morfeld, P., Groneberg, D. A., Spallek, M. F., Effectiveness of low emission zones: Large scale analysis of changes in environmental NO2, NO and NOx concentrations in 17 German cities, PloS one, 9, 2014

Quality score
+

Study type
Controlled before and after

Aim of the study
To evaluate the effectiveness of Low</td>
<td>**Number of participants**
17 German cities with LEZs

Participant characteristics

Inclusion criteria
LEZ were include only if the following criteria were met:
- Monitoring stations existed, that operated before and after the LEZ introduction and measured inside the LEZ area (index stations) and
- Monitoring stations existed, that operated before and</td>
<td>**Intervention / Comparison**
LEZs in 17 German cities that restricted cars of Euro 1 standard without appropriate retrofitting systems from entering the LEZ.
NO$_2$ concentrations were measured inside the LEZ area (index stations) and outside the LEZ area (reference stations). Data were analysed before and after the introduction of the LEZs.</td>
<td>**Outcomes**

Mean (range) NO$_2$ µg/m^3 measurements: Index stations (Ind), Reference stations (Ref), before (pre) and after (post) introduction of the LEZ
<table>
<tr><th>Ind (pre) (range)</th><th>Ind (post) (range)</th><th>Ind (difference) (range)</th><th>Ref (pre) (range)</th><th>Ref (post) (range)</th><th>Ref (difference) (range)</th></tr>
<tr><td>51.959 (0.4-392)</td><td>50.831 (1.3-436)</td><td>-1.128 (-330 to 375)</td><td>26.383 (0.4-248)</td><td>26.17 (0.5-434)</td><td>-0.212 (-215 to 317)</td></tr>
</table>
Analysis
On average, NO$_2$ concentrations were between 50 µg/m^3 and 52 µg/m^3 at the index stations and between 26 µg/m^3 and 27 µg/m^3 at the reference stations. The differences at the stations varied substantially in a range of hundreds of µg/m^3 upwards and downwards. There was a small decrease in NO$_2$ concentrations post intervention as detected by both the Index and Reference monitoring stations. A comparison of mean differences at index and reference stations indicated a crude LEZ effect estimate of about -1 µg/m^3.</td>
<td>**Limitations identified by the author**
Number and position of the monitoring stations varied between the cities studied</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>Emission Zones (LEZ) on ambient air NO_2 concentrations.

Location and setting
Germany

Length of study
5 Years

Source of funding
Not reported</td>
<td>after the LEZ introduction and measured outside the LEZ area – in a circle around the centre with a radius of about 25 km – and if outside the city area, than in no other LEZ (reference stations) and
• These monitoring stations measured NO_2 or NO (continuous measurements or diffuse samplers).

Exclusion criteria
Not reported</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full citation
Panteliadis, P., Strak, M., Hoek, G., Weijers, E., van der Zee, S., Dijkema, M., Implementation of a low emission zone and evaluation of effects on air quality by long-term monitoring, Atmospheric Environment, 86, 113-119, 2014

Quality score
+

Study type
Controlled before and after

Aim of the study
To evaluate the the long term effects of a low emission zone (LEZ) on</td>
<td>Participant characteristics
One roadside and one urban background station located within the LEZ were selected as monitoring sites:
1. Roadside station (intervention): situated on a main street. Manual traffic volume counts performed on two week days in June 2011 showed an average of approximately 15,000 vehicles per day, 690 of which were buses and heavy-duty-vehicles.
2. Background station (control): located where no motorised</td>
<td>Intervention / Comparison
Implementation of a Low Emission Zone (LEZA) in Amsterdam in which heavy duty vehicles (Euro class 0, I and II) were prohibited from entering after January 2009, and Euro III vehicles not equipped with a particulate filter after January 2010. Measurements of PM_{10} and NO_2 were available from 1 January 2007 and Elemental Carbon (EC) was available from 1 January 2008. Data on all pollutants were available until 31 December 2010 (2 years after the LEZA implementation). To</td>
<td>Outcomes

Air pollutants concentrations two years prior (2007-2008) and two years post (2009-2010) LEZA implementation at the urban background and roadside
<table>
<tr><th>Pollutant</th><th colspan="4">Urban background station</th><th colspan="4">Roadside Station</th><th colspan="4">Traffic contribution (difference)</th></tr>
<tr><th></th><th colspan="2">Prior LEZA</th><th colspan="2">Post LEZA</th><th colspan="2">Prior LEZA</th><th colspan="2">Post LEZA</th><th colspan="2">Prior LEZA</th><th colspan="2">Post LEZA</th></tr>
<tr><td></td><td>N</td><td>Mean (range)</td><td>N</td><td>Mean (range)</td><td>N</td><td>Mean (range)</td><td>N</td><td>Mean (range)</td><td>N</td><td>Mean (range)</td><td>N</td><td>Mean (range)</td></tr>
<tr><td>NO_2 (µg m^{-3})</td><td>696</td><td>31.51 (0-88)</td><td>698</td><td>30.79 (8-89)</td><td>662</td><td>53.73 (11-131)</td><td>710</td><td>50.45 (7-117)</td><td>641</td><td>22.14 (-32 to 73)</td><td>688</td><td>19.67 (-10 to 66)</td></tr>
<tr><td>PM_{10} (µg m^{-3})</td><td>445</td><td>23.31 (7.10-98.30)</td><td>546</td><td>22.74 (4.53-81.30)</td><td>590</td><td>28.65 (6.10-117.80)</td><td>651</td><td>25.95 (6.81-107.97</td><td>392</td><td>4.33 (-25.5 to 35.70)</td><td>511</td><td>2.79 (-22.23 to 46.40)</td></tr>
<tr><td>Elemental Carbon (µg m^{-3})*</td><td>71</td><td>0.81 (0.24-2.42)</td><td>141</td><td>0.73 (0.25-2.44)</td><td>90</td><td>2.55 (0.56-6.48)</td><td>161</td><td>2.13 (0.34-5.70)</td><td>70</td><td>1.69 (0.00-3.64)</td><td>141</td><td>1.41 (0.06-4.96)</td></tr>
</table>
*One year prior measurements

Effect of LEZA implementation on traffic contribution of pollutants
<table>
<tr><th>Pollutant</th><th colspan="2">LEZA effect on traffic contribution (95% CI)</th></tr>
<tr><td></td><td>Crude</td><td>Adjusted**</td></tr>
</table>
</td>
<td>Limitations identified by the author
A sensitivity analysis indicates a possible underestimation of the LEZA effect.
There is a possibility that the observed LEZA effect is biased by a general decrease in traffic.
Factors such as as improvement of vehicle technology and resulting emission reduction, and national and local policies might explain part of the observed improvement in air quality.</td>
</tr>
</table>

<table>
<tr><th>Study details</th><th>Population</th><th>Intervention / Comparator</th><th>Results</th><th>Notes</th></tr>
<tr>
<td>air quality.

Location and setting
Amsterdam, Netherlands

Length of study
4 years

Source of funding
Joint Air Quality Initiative (JOAQUIN) project</td>
<td>vehicle is allowed. The closest main street is approximately 60 m away and is separated from the monitoring site by several buildings.

Inclusion criteria
Monitoring sites were chosen according to availability of routine measurements of all selected pollutants.

Exclusion criteria
Not reported</td>
<td>evaluate the air quality effects of the LEZA, data were assessed in 2 periods: 1 January 2007 until 8 January 2009 (pre-implementation) and 9 January 2009 until 31 December 2010 (post-implementation).</td>
<td><table>
<tr><td>NO_2 ($\mu g\ m^{-3}$)</td><td>-2.47* (-3.83 to -1.11)</td><td>-2.65* (-3.70 to -1.61)</td></tr>
<tr><td>PM_{10} ($\mu g\ m^{-3}$)</td><td>-1.54* (-2.30 to -0.77)</td><td>-1.67* (-2.40 to -0.94)</td></tr>
<tr><td>Elemental Carbon ($\mu g\ m^{-3}$)</td><td>-0.28* (-0.53 to -0.02)</td><td>-0.33* (-0.52 to -0.13)</td></tr>
</table>
*$p<0.05$
**Adjusted for type of day, wind direction and wind speed.

Analysis
Overall, traffic contribution concentrations were reduced for all pollutants post-LEZA implementation. Greater reductions can be observed for the roadside station and the traffic contribution concentrations in comparison to the urban background.
Both the crude regression analysis and the adjusted analysis (for type of day, wind direction and wind speed) showed statistically significant reductions in traffic contribution concentrations for all three pollutants post intervention.</td>
<td></td>
</tr>
<tr>
<td>**Full citation**
Qadir, R. M., Abbaszade, G., Schnelle-Kreis, J., Chow, J. C., Zimmermann, R., Concentrations and source contributions of particulate organic matter before and after implementation of a low emission zone in Munich, Germany, Environmental pollution (Barking, Essex : 1987), 175, 158-67, 2013

Quality score
-

Study type
Before and After

Aim of the study
To assess the effect of a Low Emission Zone (LEZ) on particulate</td>
<td>**Participant characteristics**
The sampler for $PM_{2.5}$ was located within the LEZ near to a main road with approximately 41,000 passing vehicles per day.

Inclusion criteria
Not reported

Exclusion criteria
Not reported</td>
<td>**Intervention / Comparison**
Implementation of an LEZ. The first stage of the LEZ (October 2008) allowed vehicles with emission requirement of Euro 2, Euro 3 and Euro 4 only to enter the inner city. The second stage of LEZ started in October 2010, allowing vehicles with emission requirement Euro 3 and Euro 4 only to go through the LEZ area. Within the LEZ, samples of $PM_{2.5}$ were collected every third day from October 2006 to February 2007 (before implementation of the LEZ) and from October 2009 to February 2010 (after implementation), and</td>
<td>**Outcomes**

Elemental Carbon (EC) concentration ($\mu g\ m^{-3}$)
<table>
<tr><th></th><th colspan="3">Before LEZ (2006-2007), n=40</th><th colspan="3">After LEZ (2009-2010), n=35</th><th></th></tr>
<tr><th></th><th>Mean</th><th>Median</th><th>Range</th><th>Mean</th><th>Median</th><th>Range</th><th>t-Test (p value)</th></tr>
<tr><td>Elemental Carbon</td><td>2.50</td><td>2.00</td><td>0.80-6.50</td><td>2.20</td><td>2.10</td><td>1.00-3.90</td><td>0.04</td></tr>
</table>
Analysis
The results indicated that mean concentrations of elemental carbon were significantly decreased after implementation of the intervention.</td>
<td>**Limitations identified by the author**
None reported

Limitations identified by the review team
Only one sampling site was used within the LEZ city centre
Uneven sampling number: before (n=40); after (n=35)</td>
</tr>
</table>

Study details	Population	Intervention / Comparator	Results	Notes
organic matter. **Location and setting** Munich, Germany **Length of study** 4 years **Source of funding** Not clearly reported		samples were analysed for elemental carbon.		

Question 6: Are zoning interventions cost effective at reducing the health impact of, or people’s exposure to, traffic-related air pollution?

Study details	Inclusion / Exclusion criteria	Population	Intervention / Comparison	Method of analysis	Results	Notes
Full citation Eliasson, Jonas, A Cost-Benefit Analysis of the Stockholm Congestion Charging System, Transportation Research: Part A: Policy and Practice, 43, 468-80, 2009 **Quality score** + **Study type** Cost-benefit **Aim of the study** To determine the cost benefit analysis (CBA) of a congestion charging system in Stockholm **Location and setting** Stockholm, Sweden **Length of follow up** N/A **Source of funding** Not reported	**Inclusion criteria** Not reported **Exclusion criteria** Not reported	**Number of participants** N/A **Participant characteristics** N/A	**Intervention / Comparison** There are 18 control points located at Stockholm city entrances and exits. Vehicles are registered automatically by cameras that photograph the number plates. Those vehicles equipped with an electronic on board unit (transponder) for direct debit payment are also identified through this means.	**Method of analysis** The calculation of the value of social costs and benefits is based on observed, real-world data (rather than model-forecasted data). Consumer surplus from the congestion charge was evaluated using 'rule-of-a-half	**Primary outcomes** The congestion charges produce a net social benefit of a little less than 700 million SEK/year (around 80 million Euro/year). Environmental effects and improved traffic safety is valued to 211 million SEK/year (of which 125 million SEK/year from a 3.6% reduction in the number of traffic accidents) The yearly cost of the system (220 million SEK) includes necessary reinvestments and maintenance such as replacement of cameras and other hardware The total public financial surplus is 611 million SEK/year, of which 542 million SEK is net revenues from the charges meaning the initial investment will be recovered in around 3.5 years This entire initial cost for the system is budgeted at approximately SEK 1.9 billion (of which SEK 1,050 million was incurred prior to the start of operations) Estimated reduction in greenhouse gas emissions of 2.7% with a benefit of 64 million SEK/year along with an estimated decrease of between 1.4 and 2.8% in other emissions constituting a benefit of 22 million SEK/year and estimated 5 life years saved per year (for Stockholm county as a whole)	**Limitations identified by author** None reported
Full citation Rotaris, Lucia, Danielis, Romeo, Marcucci, Edoardo, Massiani, Jérôme,	**Inclusion criteria** Not reported **Exclusion criteria** Not reported	**Number of participants** N/A **Participant**	**Intervention / Comparison** Vehicles entering the 8 km^2 wide area between 7:30	**Method of analysis** Not reported	**Primary outcomes** The annual charge payments are estimated to be €12.4 million The Milan Ecopass scheme generated for the year 2008 an annual net benefit of €6 million. Transport users as a whole have a net loss equal to	**Limitations identified by author** Figures reported do not include penalty payments from not

Study details	Inclusion / Exclusion criteria	Population	Intervention / Comparison	Method of analysis	Results	Notes
The urban road pricing scheme to curb pollution in Milan, Italy: Description, impacts and preliminary cost–benefit analysis assessment, Transportation Research Part A: Policy & Practice, 44, 359-375, 2010 **Quality score** + **Study type** Cost-benefit **Aim of the study** Impact and cost-benefit analysis of an urban road pricing scheme (Ecopass) in Milan **Location and setting** Milan, Italy **Length of follow up** N/A **Source of funding** Not reported		**characteristics** N/A	and 19:30 are subject to the payment of a charge. The charge value was based according to the 5 Euro emission standard classes.		€————————————3.7 million (passenger cars net loss €3.9 million, freight vehicles net loss €5.3 million, bus and tram users net benefit of €5.6 million Social cost savings of €10.4 million, (€8.4 million from reduction in accidents) Total infrastructure costs equal to €7 million and annual management costs equal to €0.6 million Net impact on public finances were €0.3 million	paying the charge Official Ecopass data on the implementation of the scheme were not available - values based on informal sources

Appendix 2 Quality of included studies

EPOC Checklist

	Question									Score
	1	2	3	4	5	6	7	8	9	
Atkinson 2009	-	-	-	Unclear	-	NA	++	++	-	-
Boogaard 2012	-	-	++	Unclear	++	NA	++	++	-	+
Casale 2008	-	-	-	NA	Unclear	+	-	+	-	-
Dijkema 2008	-	-	++	-	++	+	+	++	-	+
Fensterer 2014	-	-	++	Unclear	-	NA	++	++	+	+
Invernizzi 2011	-	-	-	NA	-	NA	-	++	-	-
Jones 2012	-	-	+	NA	-	NA	++	++	-	-
Kelly 2011	-	-	++	Unclear	-	NA	++	++	-	-
Keuken 2010	-	-	NA	-	-	NA	+	-	-	-
Layfield 2003	-	-	++	NA	-	NA	NA	++	-	-
Lee 2005	-	-	+	-	++	+	NA	++	-	-
Morfeld 2014	-	-	+	Unclear	++	NA	++	++	-	+
Owen 2005	-	-	-	Unclear	Unclear	NA	+	++	-	-
Panteliadis 2014	-	-	++	NA	++	NA	+	++	-	+

Key to questions:

1. Was the allocation sequence adequately generated?
2. Was the allocation adequately concealed?
3. Were baseline outcome measurements similar?
4. Were baseline characteristics similar?
5. Were incomplete outcome data adequately addressed?
6. Was knowledge of the allocated interventions adequately prevented during the study?

7. Was the study adequately protected against contamination?
8. Was the study free from selective outcome reporting?
9. Was the study free from other risks of bias?

EPHPP Checklist

	Question																					**Score**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	
Levy 2005	Somewhat likely	NA	Cohort	No	NA	NA	NA	-	Yes	NA	Yes	Can’t tell	No	Can’t tell	80-100%	Can’t tell	Yes	Community	Community	Yes	No	**+**
Levy 2013	Can’t tell	NA	Cohort	No	NA	NA	NA	-	Yes	-	Can’t tell	Can’t tell	No	Can’t tell	Can’t tell	Can’t tell	Yes	Community	Community	No	No	**-**
Quiros 2013	NA	NA	Cohort	No	NA	NA	Yes	60-79%	NA	NA	Yes	Can’t tell	Yes	NA	80-100%	No	No	Other	Other	Can’t tell	Can’t tell	**+**
Qadir 2013	NA	NA	Cohort	No	NA	NA	Yes	<60%	NA	NA	Yes	Can’t tell	No	-	NA	No	No	Other	Other	Yes	Can’t tell	**-**

Key to questions:

1. Are the individuals selected to participate in the study likely to be representative of the target population?
2. What percentage of selected individuals agreed to participate?
3. What is the study design?
4. Was the study described as randomised?
5. Was the method of randomisation described?
6. Was the method of randomisation appropriate?
7. Were there important differences between groups prior to the intervention?
8. If yes, what percentage of relevant confounders were controlled (either in the design [e.g. stratification, matching] or analysis)?
9. Was/were the outcome assessor/s aware of the intervention or exposure status of participants?
10. Were the study participants aware of the research question?
11. Were data collection tools shown to be valid?
12. Were data collection tools shown to be reliable?
13. Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?
14. What percentage of participants completed the survey?
15. What percentage of participants received the allocated intervention or exposure of interest?
16. Was the consistency of the intervention measured?
17. Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results?
18. What is the unit of allocation?
19. What is the unit of analysis?
20. Are the statistical methods appropriate for the study design?
21. Is the analysis performed by intervention allocation status (i.e. intention to treat) rather than the actual intervention received?

Economic checklist

	Question																					Overall Assessment
	Section 1										Section 2											
	1	2	3	4	5	6	7	8	9		1	2	3	4	5	6	7	8	9	10	11	
Elliason 2006	+	++	+	+	+	+	-	+	+		+	+	+	+	+	+	Unclear	Unclear	NA	-	-	+
Rotaris 2010	+	++	+	+	+	-	NA	+	+		+	-	+	+	-	+	-	+	NA	+	-	+

Section 1: Applicability
1. Is the study population appropriate for the review question?
2. Are the interventions appropriate for the review question?
3. Is the system in which the study was conducted sufficiently similar to the current UK context?
4. Are the perspectives clearly stated and are they appropriate for the review question?
5. Are all direct effects on individuals included, and are all other effects included where they are material?
6. Are all future costs and outcomes discounted appropriately?
7. Is QALY used as an outcome, and was it derived using NICE's preferred methods? If not, describe rationale and outcomes used in line with analytical perspectives taken (item 1.4 above).
8. Are costs and outcomes from other sectors fully and appropriately measured and valued?
9. Overall judgement

Section 2: Study limitations
1. Does the model structure adequately reflect the nature of the topic under evaluation?
2. Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?
3. Are all important and relevant outcomes included?
4. Are the estimates of baseline outcomes from the best available source?
5. Are the estimates of relative intervention effects from the best available source?
6. Are all important and relevant costs included?
7. Are the estimates of resource use from the best available source?
8. Are the unit costs of resources from the best available source?
9. Is an appropriate incremental analysis presented or can it be calculated from the data?
10. Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?
11. Is there any potential conflict of interest?
12. Overall assessment

Modelling checklist

	Relevance					Credibility												Score
	1	2	3	4	Overall	5	6	7	8	9	10	11	12	13	14	15	Overall	
Ahn 2009	Yes	No	No	Yes	Sufficient	Not enough info	Not enough info	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not enough info	Not enough info	Sufficient	-
Boulter 2001	Yes	No	No	Yes	Sufficient	Yes	Not enough info	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not enough info	Not enough info	Sufficient	-
Ghafghazi 2014	Yes	No	No	Yes	Sufficient	Yes	Not enough info	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not enough info	Not enough info	Sufficient	+
Ghafghazi 2015	Yes	No	No	Yes	Sufficient	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not enough info	Not enough info	Sufficient	+

Key to questions:

Relevance

1. Is the population relevant?
2. Are any critical interventions missing?
3. Are any relevant outcomes missing?
4. Is the context (settings and circumstance) applicable?
5. Is external validation of the model sufficient to make its results credible for your decision?
6. Is internal verification of the model sufficient to make its results credible for your decision?
7. Does the model have sufficient face validity to make its results credible for your decision?
8. Is the design of the model adequate for your decision problem?
9. Are the data used in populating the model suitable for your decision problem?
10. Were the analyses performed using the model adequate to inform your decision problem?
11. Was there an adequate assessment of the effects of uncertainty?
12. Was the reporting of the model adequate to inform your decision problem?
13. Was the interpretation of results fair and balanced?
14. Were there any potential conflicts of interest?
15. If there were potential conflicts of interest, were steps taken to address these?