Vehicular emission control strategies

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Centre for Science and Environment
Fundamentals of controlling air pollutant emissions from motor vehicles

New vehicle Standards

- Technology neutral (but technology-forcing…) emissions standards for new vehicles.
- Must consider emissions from all mobile sources
- Limit values only as good as: - Compliance and enforcement - Real-world performance

Fuel quality standards

- High fuel quality (especially low sulfur levels) enables advanced emission control technologies to be deployed in the fleet.
- Fuel quality compliance programs critical to prevent damage to engines and prevent mis-fueling

In-use vehicle emission control

- In-use vehicle emission control
- Comprehensive program includes:
  - Catching gross-emitters (I/M, remote sensing, maintenance, etc.)
  - Cleaner fuels
  - Scrap-page, replacement programs
  - Retrofit programs
  - Low emission zones

Fuel quality standards

In-use vehicle emission control
Emission norm roadmap

India:
- Bharat Stage II: Passenger cars in 13 Major cities
- Bharat Stage III: Bharat Stage IV
- Bharat Stage I: Bharat Stage II
- Bharat Stage III (from 2017)

Europe:
- Euro III
- Euro IV
- Euro V
- Euro VI & beyond

Key:
- Implemented
- Plan

Timeline:
- 2000
- 2005
- 2010
- 2015
- 2020

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Diesel cars
Legal license to pollute

Particulate norms for diesel car (Particulate emissions from petrol cars are negligible and not regulated)

<table>
<thead>
<tr>
<th></th>
<th>Diesel cars</th>
<th>Petrol cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 3 (India)</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Euro 4 (India selected cities)</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Euro 5 (2009 in Europe)</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Euro 6 (2014 in Europe)</td>
<td>0.02</td>
<td>0.01</td>
</tr>
</tbody>
</table>

NOx norms for petrol and diesel cars. (Diesel emissions equalize with petrol only at Euro VI level)

<table>
<thead>
<tr>
<th></th>
<th>Diesel cars</th>
<th>Petrol cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 3 (India)</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Euro 4 (India selected cities)</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Euro 5 (2009 in Europe)</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Euro 6 (2014 in Europe)</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Note: PM emissions from petrol vehicles are so negligible that these are not regulated in petrol vehicles

Source: Based on data available in www.dieselnet.com

Diesel cars legally allowed to emit 3 times more NOx
Several times more PM
India to leapfrog……

Current: Bharat Stage IV nation-wide

2020: Bharat Stage VI with in-compliance regulations
BS VI standards implementation by 2020 is a major step forward.
Motorisation and dieselisation

Need stringent and preventive action and decision here to influence the future stock -- several times higher than the legacy stock.

Share of diesel cars in new car sales

Source: CSE
Comparison between China 6, India/Euro 6, Tier 2 and LEV 3 standards

Notes:
[1] Emissions limits are those for Type I test (regular temperature, cold start emission test)
[2] For diesel light-duty vehicles, Europe and China regulate HC and NOx, instead of NMOG+Nox
[3] For gasoline light-duty vehicles, Europe and China regulate NMHC and NOx, instead of NMOG+Nox
[4] This analysis simply compares direct emission limits, and does not take into consideration the differences in test cycle and procedures among various regulatory programs

Source: ICCT
Benefit of Euro-VI/equivalent norms in different regions of the world

- Euro VI norms will reduce tailpipe PM2.5 emissions by 74% from 2015 levels by 2030.
- Once implemented across the G-20, nearly 90% of new LDVs and HDVs sold worldwide will meet world-class emissions standards, compared to only half of new vehicles sold today.

Source: ICCT 2017, impacts of world-class vehicle efficiency and emissions regulations in select G20 countries (India, China, Australia, Brazil, Mexico and Russia)
In use vehicle inspection & maintenance and compliance programme
Norms for on-road diesel vehicles

Smoke opacity tests

- **India:** 50 HSU for BS-IV vehicles and 65 HSU for pre-Euro IV diesels vehicles
- **Singapore:** 40 HSU
- **Indonesia, Thailand, Hong Kong, Malaysia:** 50-HSU for all vehicles

China is developing a nationwide I/M system for evaluating NOX emissions from in-use HDVs.

Hong Kong: Snap idle tests on chassis, smoky vehicle programme etc
Poor failure rate in pre-2010 vehicles

Diesel vehicles: Smoke density norm of 65HSU
-- Failure rate 6%

% of total vehicles in the sample

-20 20-30 30-40 40-50 50-60 60-65 65-
8 26 12 18 28 3 6

Proposed norm: 50 HSU for BSIV and subsequent
Current norm: 65 HSU
Why smoke opacity tests are of no use in new diesel vehicles?

- No accurate correlation found between smoke readings and PM mass. Smoke is not a good surrogate for tiny particles.

- PM and NOx emissions cannot be tested.

- Smoke tests on chassis dynanometer for diesel vehicles: Hong Kong and China.

- Smoke readings get affected by other pollutants. There is need for improvement in resolution, stability, and noise to allow opacity measurements in advanced diesel engines.

- NO2 – smoke trade-off: Repairs to reduce visible smoke may actually increase both the number of ultrafine particles and NOX emissions.
Checking Petrol vehicles……

These vehicles are tested for carbon-monoxide, hydrocarbon, and lambda (indicates optimal conditions for proper functioning of catalytic converters)
### Norms for Petrol/CNG/LPG vehicles

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Idle Emission limits</th>
<th>High Idle Emission Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO%</td>
<td>HC(n-hexane equivalent) ppm</td>
</tr>
<tr>
<td>2 Wheelers (2/4-stroke) (Vehicles manufactured on and before 31st March 2000)</td>
<td>4.5</td>
<td>9000</td>
</tr>
<tr>
<td>2 Wheelers (2-stroke) (Vehicles manufactured between 31st March 2000 and 31st March 2010)</td>
<td>3.5</td>
<td>6000</td>
</tr>
<tr>
<td>2 Wheelers (4-stroke) (Vehicles manufactured between 31st March 2000 and 31st March 2010)</td>
<td>3.5</td>
<td>4500</td>
</tr>
<tr>
<td>2 Wheelers (2-stroke) (Vehicles manufactured after 31st March 2010)</td>
<td>3.0</td>
<td>4000</td>
</tr>
<tr>
<td>2 Wheelers (4-stroke) (Vehicles manufactured after 31st March 2010)</td>
<td>3.0</td>
<td>3000</td>
</tr>
<tr>
<td>3 – Wheeler (2/4-stroke) (Vehicles manufactured on and before 31st March 2000)</td>
<td>4.5</td>
<td>9000</td>
</tr>
<tr>
<td>3 – Wheeler (2-stroke) (Vehicles manufactured after 31st March 2000)</td>
<td>3.5</td>
<td>6000</td>
</tr>
<tr>
<td>3 – Wheeler (4-stroke) (Vehicles manufactured after 31st March 2000)</td>
<td>3.5</td>
<td>4500</td>
</tr>
<tr>
<td>4-wheelers manufactured as per Pre Bharat Stage-II norms</td>
<td>3.0</td>
<td>1500</td>
</tr>
<tr>
<td>4-Wheelers manufactured as per Bharat Stage-II or Bharat Stage-III emission norms</td>
<td>0.5</td>
<td>750</td>
</tr>
<tr>
<td>Petrol driven 4-wheelers manufactured as per Bharat Stage-IV norms</td>
<td>0.3</td>
<td>200</td>
</tr>
<tr>
<td>Compressed Natural Gas/Liquefied Petroleum Gas driven 4-wheelers</td>
<td>0.3</td>
<td>200</td>
</tr>
</tbody>
</table>
The Lambda fiasco

<table>
<thead>
<tr>
<th>Make</th>
<th>Lambda specification</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>--- Rich (Probability for high CO and HC)</td>
<td>Desired limit</td>
</tr>
<tr>
<td></td>
<td>0.93</td>
<td>0.95</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Motors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maruti</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tata Motors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M&amp;M</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lambda value for spark ignition engines

\textit{lambda value of 1± 0.03 ensures optimum emission control}

- The value of the coefficient $\lambda$ (lambda) is the ratio of the actual air/fuel ratio (AFR) to stoichiometric. For gasoline engine air/fuel ratio (AFR) is equal to $14.7:1$ the value of $\lambda = 1$. When the engine is running on a "rich" mixture, then $\lambda < 1$, and engine emissions contains unburnt fue.
The Lambda fiasco

Make-wise lambda result  \(\text{lambda value of } 1 \pm 0.03\)

<table>
<thead>
<tr>
<th>Make [No. of cars in the sample]</th>
<th>Within 0.97-1.03</th>
<th>Outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>All [1,144]</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Maruti [771]</td>
<td>82%</td>
<td>18%</td>
</tr>
<tr>
<td>Hyundai [226]</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Honda Siel [41]</td>
<td>93%</td>
<td>7%</td>
</tr>
<tr>
<td>Ford [27]</td>
<td>67%</td>
<td>33%</td>
</tr>
<tr>
<td>GM [20]</td>
<td>90%</td>
<td>10%</td>
</tr>
<tr>
<td>Fiat [16]</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Toyota [14]</td>
<td>79%</td>
<td>21%</td>
</tr>
<tr>
<td>Tata Motors [8]</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Daewoo [7]</td>
<td>71%</td>
<td>29%</td>
</tr>
<tr>
<td>Mitsubishi [6]</td>
<td>83%</td>
<td>17%</td>
</tr>
<tr>
<td>HM [4]</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>Skoda [3]</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
Visual checks

**Hong Kong:** Spotter programs -- More than 5,000 trained citizen volunteer spotters. Resulted in thousands of vehicles being repaired each year.

**Other countries:** Authorities have hotlines consumers may call to report smoky vehicles.

Remote sensing: Checks vehicle’s exhaust with infrared light beams for CO2, CO, and HCs, and/or UV light to estimate concentrations of NOX. Useful tool to identify gross emitters; evaluate fleet-wide trends, and effectiveness of I/M programs. But expensive. California has implemented this.
Road side checks: RSD tests in Kolkata
Good I/M programmes can reduce pollution levels

- I&M in many countries have improved air quality and reduced transport emissions.
- Older programmes have reported improvement
  - European Union: CO reduced by 17 to 35%, HC 12.5% to 25%, negligible benefit in Nox at 2.5% to 5%
  - USA Petrol cars -- CO reduced by 13 to 74%, HC 14% to 68%, NOx at 6% to 40%.

- India estimated that various I&M-related actions in India reduced 0.5 million ton HC+ NOx+CO emissions; and up to 15,000 ton reduction of PM emissions. (Shakti)
- If not done well it may lead to enormous investment without results
- Several US cities: Actual reductions from the I/M programs generally much lower than expected due to overly optimistic assumptions about consumer compliance, gross emitter identification rates, and the effectiveness of repair.
CSE PUC audit and review

- Manual PUC centres – not linked with central servers
- Limited data recording
- Compliance level only 23%
- Poor compliance to test procedures
- Cheating software, mechanisms
Summary of observations

- Problem of quality control and assurance
- Poor data recording and reporting
- Poor compliance with the programme
- Poor failure rate – nearly all vehicle pass
- Lax PUC norms
- Current smoke density test for diesel vehicles ineffectual
- Legal framework for monitoring PUC centres weak
- Concerns about skills of operators
- Decentralised testing centres vs. centralized testing
PUC reforms

- Limit the numbers of PUC centres, upgrade them and bring them under strong supervision and quality control
- Ensure 100% compliance by linking annual vehicle insurance with PUC certificates
- Introduce automatic online network for transmission of PUC data to the central server to minimize manual interference and allow proper analysis of data for remote auditing of PUC centres
- Mandate pre-payment of PUC fees before the tests are conducted
- Make lambda test for petrol cars mandatory
- Strengthen inspection for quality control and licensing programme
Introduce well equipped mobile test centres and a programme to check visibly polluting vehicles

Phase in centralized testing centres capable of conducting automatic and upgraded tests for commercial vehicles on a priority basis

Integrate OBD with inspection and maintenance programme

Tighten PUC norms and test procedures – especially for diesel vehicles (Coordinate with MORTH)
Next generation emissions control systems need advanced I/M.
Draw lessons from the Volkswagen emissions fraud case.....
While emissions standards decline, real-world diesel NOx remained high.

Volkswagen cars fitted with defeat devices to pass tests, but emit high NOx when on road

Modern emission control devices

The pinch

11 million affected vehicles, which Volkswagen may have to recall. Fixing all would cost the earth

up to $18 bn of civil penalty Volkswagen could face from US Environmental Protection Agency

39.8% is the drop in Volkswagen’s share value within a week after the scandal broke on September 18
Unacceptable level of emissions

- US EPA standard: 0.04 g/km
- Euro VI standard: 0.08 g/km
- Bharat stage IV standard: 0.25 g/km

**Highway**
- Jetta: 15 times more
- Passat: 9 times more

**Urban (Los Angeles)**
- Jetta: 25 times more
- Passat: 20 times more

**Urban (San Diego)**
- Jetta: 37 times more
- Passat: 17 times more

**Urban (San Francisco)**
- Jetta: 20 times more
- Passat: 20 times more

Source: Based on the ICCT and West Virginia University study
2016 PEMS testing of BS IV vehicles

Source: ICCT
PEMS results – 2016 BS IV Diesel SUV

- NOx standard for this SUV diesel is **5x NOx Std for Petrol**
- NOx real driving emissions: **4x - 6x NOx standard**.
- NOx real driving emissions from BS IV diesel SUV are **25x - 65x more than small petrol car**

*Source: ICCT*
Real Driving Emissions Test Procedures and Standards by 2017 with a conformity factor of 1.6 for 2017 and 2018 dropping to 1.2 or possibly 1.3 for 2018/2019. Will adopt tighter test cycle.

In Use Testing of Random Vehicles: The proposed European Type Approval Authority to do testing of random in use vehicles samples and make the data publicly available. Protocols for testing will include vehicles, types of tests, etc.

Voluntary label system: Labeling scheme linked to low emissions zones. If manufacturers could give tighter standards of Euro VI preferential treatment to accelerate the city’s efforts to achieve the air quality Directives. With label the consumers could choose the cleaner vehicles might be a strong incentive to accelerate the process.

Creation of a European Type Approval Authority
Integrating on-board diagnostic (OBD) monitoring with vehicle inspection and maintenance programme
Why On board diagnostics?

• If a problem or malfunction is detected, the OBD II system illuminates a warning light on the vehicle instrument panel to alert the driver.

• This warning light will typically display the phrase "Check Engine" or "Service Engine Soon," and will often include an engine symbol.

• The OBD system stores important information about any detected malfunction so that a repair technician can accurately find and fix the problem. **No guess work.**

• Smog Check inspections in USA for post 2000 model vehicles are now primarily based on an inspection of the OBD II system; Tailpipe testing is no longer required.
OBD intervention

I/M program
In-use emissions monitoring

http://etecnologytips.com/own-made-automotive-diagnostic/
Leverage OBD performance data for I/M in India

- In India OBD I is required from 1 April 2010.

- OBD II is required from 1 April 2013 for Bharat Stage IV light-duty vehicles of all categories.

- The OBD threshold limit exceedance indicates faults in engine and systems of emission control

- In India OBD data not made public yet

- RTOs to evaluate integration of OBD with I/M programme
Benefits of OBD to Consumers

• Identifies emission-related components covered under warranty
  – Eliminates unnecessary repairs
  – Fault codes and other scan tool data give information about area of malfunction or a specific component

• Consumer protection
  – Durability incentivized by cost of warranty repairs / customer satisfaction

• Early Detection of Malfunctions
  – Prevent secondary malfunctions (e.g., detect misfire before catalyst damaged)

--- Increase durability requirement: Consider one step forward before Euro VI standard

-- Emissions warranty and recall programme: Enforce immediately.

-- Assess RSD and other testing mechanisms for enforcement

-- Globally nations are preparing for a new regime:
  -- Not to exceed standards -- to limit off-cycle emissions.

-- On board monitoring
Thank You