POSITION BRIEF

MAY 31, 2018

TECHNICAL CONSIDERATIONS FOR IMPLEMENTING A REAL DRIVING EMISSIONS TEST FOR PASSENGER VEHICLES IN INDIA

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BACKGROUND

In 2011, a European real-driving emissions (RDE) working group was tasked with developing a new, complementary test procedure that would be representative of normal vehicle use and cover a range of driving conditions. In the immediate aftermath of Dieselgate coming to light in 2015, the European Union (EU) adopted the first two pieces of legislation, (EC) 2016/427 and (EC) 2016/646, designed to implement the RDE test procedure. A third package of regulations published in June 2017, (EC) 2017/1151 and (EC) 2017/1154, introduced provisions for cold start, regeneration events, and hybrid powertrains testing. The fourth and latest RDE legislative package adopted by EU member states in May 2018 addressed in-service conformity testing by granting type approval authority and laboratory accreditation.

Adoption of real-driving emissions testing has expanded to other regions. China has adopted RDE testing as part of the China 6 regulatory program[1]. The China 6 standard will take effect beginning on July 1, 2020. Unlike the previous standard phases, which closely follow the European emission standards, the China 6 standard combines best practices from both European and U.S. regulatory requirements in addition to creating its own. One of the most interesting features of the China 6 regulation is that the WLTC emission standard limits for NO_x are fuel neutral, identical for petrol and diesel cars: 35 mg/km. This directly affects the RDE compliance evaluation, placing an even level of compliance for petrol and gasoline (a departure from the European approach that favors diesel technology), while addressing the environmental challenges faced in Chinese cities.

The latest Automotive Industry Standard (AIS) 137 draft for adoption of Bharat Stage (BS) VI includes a proposed RDE protocol for India[2]. Bharat Stage VI emission standards will apply to light- and heavy-duty vehicles, as well as two- and three-wheeled vehicles. As proposed, the BS VI standards will go into effect for all vehicles in these categories manufactured on or after April 1, 2020. The draft BS VI proposal specifies mass emission standards, type approval requirements, and on-board diagnostic (OBD) system and durability levels for each vehicle category and sub-classes therein. The RDE protocol is one component of that regulatory proposal.

This position brief makes specific recommendations regarding the adoption of RDE testing in India. The AIS 137 draft captures several elements of the EU RDE packages 1 and 2, but critical RDE components included in packages 3 and 4 are missing in AIS 137. Further, some elements of the RDE test protocol need to be adjusted to suit the Indian driving conditions.

1 Hui He, Liuhanzi Yang, *China's Stage 6 emission standard for new light-duty vehicles (final rule)* (ICCT: Washington DC, 2017), Retrieved from http://www.theicct.org/publications/chinas-stage-6-emission-standard-new-light-duty-vehicles-final-rule

2 Ministry of Road Transport and Highways (MoRTH). *Finalized Draft Automotive Industry Standard Document on Test Method, Testing Equipment and Related Procedures for Testing Type Approval and Conformity of Production (Cop) of category M and N Vehicles having GVW not exceeding 3500 kg for Emission as per CMV Rules 115, 116 and 126 PART-3 BS VI Emission Norms*. Retrieved from http://morth.nic.in/showfile.asp?lid=3173

The recommendations are geared towards ensuring that implementation of an Indian RDE program would narrow the gap between laboratory and on-road emissions performance of vehicles that should meet Bharat Stage (BS) VI emissions standards.

Although RDE testing is conducted on public roads open to traffic, there are provisions to ensure that test trips cover a broad range of driving conditions typically encountered by drivers. Boundaries have been set to define and cap what constitutes a valid RDE trip. The current RDE programs in Europe and China have also implemented restrictions to evaluate the portable emissions measurement system (PEMS) data and determine compliance. An Indian RDE program should adopt aspects of the EU and Chinese RDE programs, while adjusting boundary conditions to better reflect Indian driving conditions.

We suggest the following changes to the AIS 137 proposal for the RDE testing program adoption in India:

» **Speed definitions for urban, rural and motorway operation**: We recommend reducing the speed range definitions to better reflect Indian driving conditions for RDE testing. The data shows that defining the three sections with two cut points set at 30 km/h and 50 km/h, with urban driving defined as under 30 km/h and motorway driving defined as over 50 km/h, results in time and distance distributions similar to those already in place for the European RDE testing, while keeping the distance-specific emissions within the expected emissions behavior of diesel technology. Using the higher speed cut points currently proposed in Option 1 of 50 km/h and 70 km/h, or Option 2 of 60 km/hr and 90 km/h would result in non-representative data analysis and regulatory evaluation.

» **Dissemination of RDE test results**: We appreciate the intention to adopt transparency measures aimed at making RDE test results available to interested third-parties. However, access to those results as currently proposed will be available to only those involved in testing and approval procedures who have access to the unique identification number of a PEMS testing family. We recommend that starting April 2020, the Ministry of Road Transport and Highways (MoRTH) should directly, or though one of the designated testing agencies, compile and publish the RDE results with unrestricted public access. The only data requirements needed to access the RDE test information should be manufacturer, model year, model name and variant.

» **Trip Evaluation**: We recommend the adoption of the Total NO_x emissions evaluation as presented in the EU RDE 4th regulatory package. This method provides closer results to real-driving raw emissions, while ensuring urban driving emissions are properly evaluated during testing and addressed by manufacturers.

» **Conformity Factor**: We recommend that India adopt a conformity factor (CF) timeline that starts RDE implementation with CF= 1.43 for NO_x emissions in April 2023 and moves to CF= 1.0 by April 2026. Multiple manufacturers and technology suppliers are already publicly showcasing application of after-treatment systems capable of meeting conformity factor of 1 on the road.

» **Validity of RDE Test**: With the introduction of the fourth RDE regulation in EU, the moving average window (MAW) method will become the only method for determining the validity of a RDE test. The power binning method was never fully adopted for regulatory purposes. Thus, we recommend moving directly to the MAW method and dropping the power binning method and all references to it.

» **In-Service Conformity regulation**: We recommend adopting PEMS-based tests as part of the In-Service Conformity (ISC) regulation for passenger vehicles in India and placing the testing responsibility with the type-approval authority. Manufacturer data would still be required but only as a way to screen for potential ISC tests subjects.

The following sections explain the rationale behind our recommendations in detail.

DEFINITION OF URBAN, RURAL AND MOTORWAY CONDITIONS (ARTICLE 6.0 TRIP REQUIREMENTS)

Studies on vehicle speed distributions in Indian cities show that most driving is done under very low speed conditions. According to GPS tracking data gathered

Table 1. Current AIS 137 proposal options for Urban/Rural/Motorway definitions

AIS 137 Option	Urban	Rural	Motorway
Option 1	$V_{speed} \leq 50$ km/h	$50 < V_{speed} < 70$km/h	$V_{speed} > 70$km/h
Option 2	$V_{speed} \leq 60$ km/h	$60 < V_{speed} < 90$km/h	$V_{speed} > 90$km/h

by the Indian Institute of Technology of Madras,[3] about 90% of the time a vehicle in New Delhi travels at speeds below 45 km/h, and traffic congestion due to higher annual vehicle sales resulted in average speed drops of about 5 km/h between 2013 and 2014. One study.[4] shows that in New Delhi, cars spend 65% of their time being operated below 30 km/h, and traffic data shows that 99% of the road grid sustains cars at speeds below 50 km/h. Considering that distance-specific diesel NO_x emissions (gNO_x/km) are higher at the lower speed range than average numbers,[5] it is extremely important to properly define the speed ranges for urban, rural, and highway driving for Indian conditions.

The current RDE proposal for India, presented in Table 1, includes two options for speed cut points defining urban, rural and motorway options. Note that Option 2 is numerically equivalent to the European speed classification for urban, rural, and motorway (U/R/M) conditions with cut points of 60 and 90 km/h.

ICCT reviewed the effect of the speed cut point definitions in terms of time and distance distributions, as well as distance specific NO_x emissions. The data used for this analysis comes from a PEMS testing project carried out in New Delhi region, and includes 3 PEMS tests for 3 different vehicles (one compact petrol car, one compact diesel car, and one diesel SUV), covering 9 PEMS test in total.[6] Two of the three PEMS tests were run using the RDE European criteria for trip validity and dynamic conditions (VxA and RPA);[7] thus, these tests present higher average speeds, accelerations, and VxA values, as well as higher fuel consumption. The third PEMS test was run following typical Indian driving conditions, without using trip validity criteria defined under European RDE testing conditions.

Figure 1 presents the average time and distance distributions for both types of trips. Under European RDE testing criteria, presented here as RDE, the vehicles were driven under higher ranges of speed conditions. When driving under typical Indian conditions (IND), the speed was limited to below 90 km/h during the tests. The distributions suggest that the current speed cut points based on the European RDE testing criteria, shown in *Option 2,* would not be adequate for Indian cities, as literature, and this dataset suggests that most of the driving in India involves speed ranges below 70 km/h.

We performed an analysis of the effect of different speed cut point sets on PEMS data analysis and evaluation. Table 2 shows the different cases studied. The first case, RDE EU, includes data from 6 different PEMS tests carried out in 3 vehicles in New Delhi while trying to mimic European driving style to meet the European RDE trip validity criteria. The other three cases are analysis performed on data from 3 PEMS tests carried out while driving in New Delhi,

3 Neema Davis, Harry Raymond Joseph, Gaurav Raina, Krishna Jagannathan, *Congestion costs incurred on Indian Roads: A case study for New Delhi,* Physics and Society, August 2017. Retrieved from: physics.soc-ph, eprint arXiv:1708.08984.

4 Rahul Goela, Sarath K. Guttikundaab, Dinesh Mohana, Geetam, Tiwaria, *Benchmarking vehicle and passenger travel characteristics in Delhi for on-road emissions analysis.* Travel Behaviour and Society, Volume 2, Issue 2, May 2015, Pages 88-101. doi.org/10.1016/j.tbs.2014.10.001

5 Vicente Franco, Francisco Posada Sánchez, John German, Peter Mock *Real World Exhaust Emissions from Diesel Cars* (ICCT: Washington DC, 2014). Retrieved from: https://www.theicct.org/sites/default/files/publications/ICCT_PEMS-study_diesel-cars_20141010.pdf

6 The International Centre of Automotive Technology (IMT Manesar, Gurgaon, India), *PEMS testing report for tree diesel passenger vehicles* (ICCT: Washington DC 2017) Retrieved from: https://www.theicct.org/publications/laboratory-and-road-emission-testing-use-passenger-vehicles-india

7 Relative positive acceleration (RPA) and velocity times acceleration (VxA) are used to define the low and high dynamic boundary conditions, respectively, for a trip to be considered valid. RPA is the integral of the product of instantaneous velocity and positive acceleration over a section of the trip. RPA tends to zero when the trip is driven very smoothly. Setting a lower limit would prevent abnormally soft driving. VxA is a good surrogate for power demand. Setting an upper limit with VxA would prevent someone to drive too aggressively A trip that resulted in very aggressive driving, high VxA, or very mild driving (low RPA) is considered invalid for RDE evaluation. This ensures that the vehicle was driven under normal driving conditions, not too aggressively or too passively, which would make the PEMS measured NO_x emission representative of normal driving. As NO_x emissions are proportional to engine load demand, driving a vehicle too aggressively would result in high engine-out NO_x emissions, while driving a vehicle too passively would result in very low NO_x engine-out emissions. Thus, RPA and VxA provide some bounds to make sure the test are carried out with a vehicle that is driven under normal driving conditions.

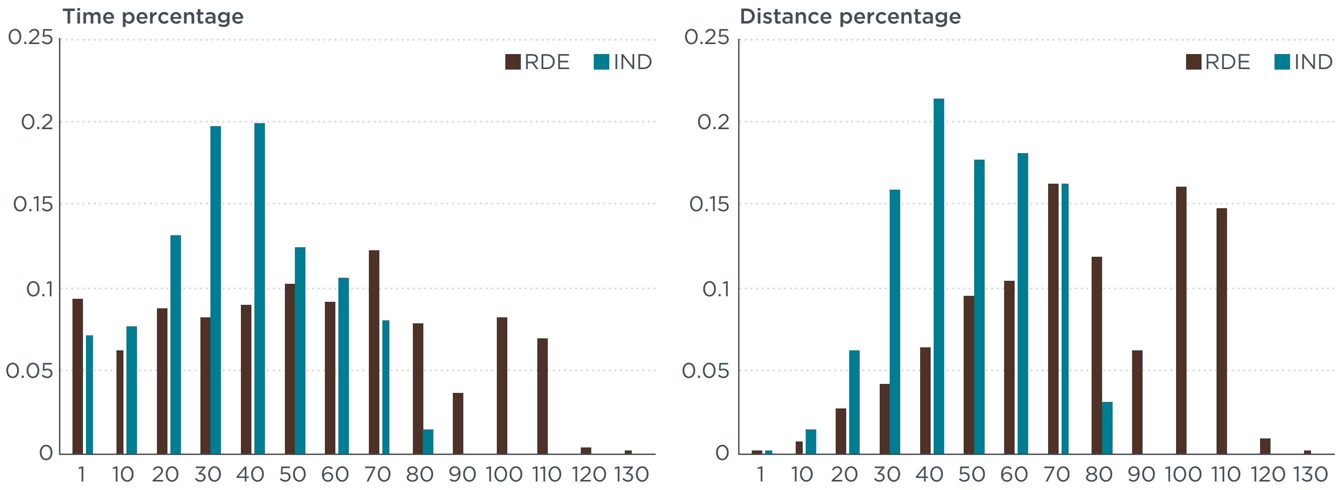

Figure 1. Average time and distance distributions for 9 PEMS tests on 3 Indian vehicles. RDE driving meets the European RDE requirements; IND driving is representative of new Delhi driving style averaged for three vehicles operated in work-day driving conditions

Table 2. Urban, rural and motorway definition options for regulatory analysis

Analysis case	U/R/M speed cut points	Data source	Nomenclature used in this document
RDE EU	60/90 km/h	6 PEMS tests meeting European RDE criteria	*RDE EU 60/90 km/h*
Option 1	50/70 km/h	3 PEMS tests under India driving style	*Opt. 1: 50/70 km/h*
Option 2	60/90 km/h	3 PEMS tests under India driving style	*Opt. 2: 60/90 km/h*
New proposal for RDE in India	30/50 km/h	3 PEMS tests under India driving style	*RDE IND 30/50 km/h*

without attempting to meet any trip validity criteria. Option 1 and Option 2 correspond to the regulatory proposal. Our new proposal for RDE speed cut points in India (RDE IND) is presented after careful PEMS data evaluation.

A closer look at the time distribution under the different speed cut points is presented in Figure 2. The figure shows the time distributions for Urban, Rural, and Motorway portions of the trip, as an average for all three vehicles tested. The first group shows the RDE European driving cut points time distributions. The regulatory proposal Option 1 and Option 2 cover the 50/70 and 60/90 km/h cut points. We propose a lower range for the speed cut points: 30 and 50 km/h. Note that both regulatory proposals, Options 1 and 2, result in very low time contributions to motorway operation. Our proposal to reduce the cut points to 30/50 km/h results in time distributions that correspond to the European RDE model, with approximately 60% of the test time comprised of

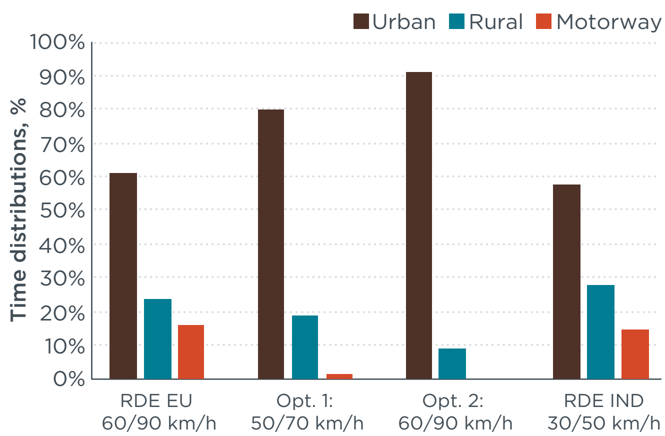

Figure 2 Driving time distributions under different speed cut point options. Each urban, rural, and motorway bar group adds up to 100%. These time distribution groups are defined under different speed cut point classifications: RDE EU 60/90 is the time distribution applied to data from European style of driving. Opt. 1 50/70 and Opt. 2 60/90 are the AIS 137 options applied to data representative of India's driving characteristics. The 30/50 group corresponds to ICCT's proposed cut points applied to Indian driving characteristics.

urban driving, and also aligns with literature by Davis et al.[8] and Goel et al.[9] as presented before.

The speed cut points also have important effects in terms of distance distributions. Figure 3 shows the same four driving classification groupings as presented in the previous figure and adds distance share requirement limits (33% each, with an accepted variance of 10% for urban, rural, and motorway shares, and a minimum 29% share for urban driving). The first group, RDE EU 60/90 km/h, shows a good balance for each trip section under the 60/90 km/h cut points that is very close to 33% each. The trip dynamics for this PEMS tests were forced to mimic the European driving style on Indian roads. For the PEMS tests that closely resemble Indian driving characteristics, both current regulatory options show excessive distance shares for urban driving, and very low motorway shares. Our proposed 30/50 km/h cut points presents U/R/M shares that more closely align with European U/R/M distributions and meet the distance distribution conditions.

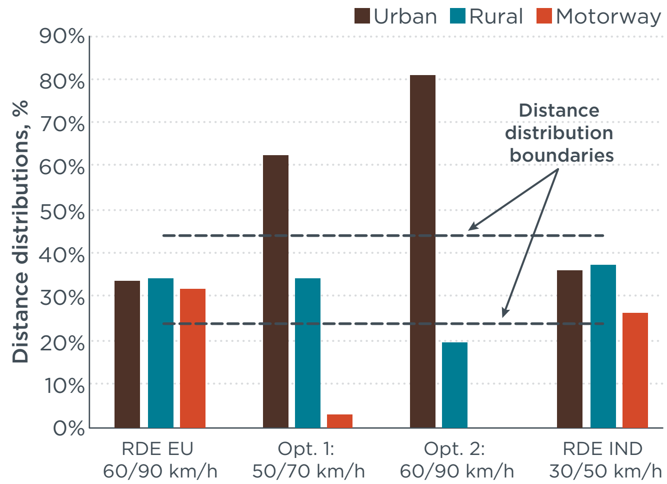

Figure 3. Driving distance distributions under different speed cut point options. Each urban, rural, and motorway bar group adds up to 100%. These time distribution groups are defined under different speed cut point classifications: RDE EU 60/90 is the time distribution applied to data from European style of driving. Opt. 1 50/70 and Opt. 2 60/90 are the AIS 137 options applied to data representative of India's driving characteristics. The 30/50 group corresponds to ICCT's proposed cut points applied to Indian driving characteristics.

Next, we investigated nitrogen oxides (NO_x) emissions performance as a function of speed for the two diesel vehicles. Distance-specific NO_x emissions (g/km) are typically higher at low speed driving and at higher speeds, as shown in Figure 4. At low speeds the shorter distance in the denominator of distance specific emissions (grams/distance) drives the values up; at higher speeds and engine loads, the emissions rates are higher than average, driving the distance-specific values up. This behavior is more clearly shown in the compact diesel vehicle. The diesel SUV exhibits a less consistent behavior, with peak emissions occurring at 45-50 km/h, that could be associated with driving style variability, or exhaust gas recirculation calibration for that particular model.

The effect of speed cut points in distance-specific NO_x emissions is presented in Figure 5 for the compact diesel car and the diesel SUV. Each urban, rural, and motorway average value was calculated by selecting the corresponding emission rates

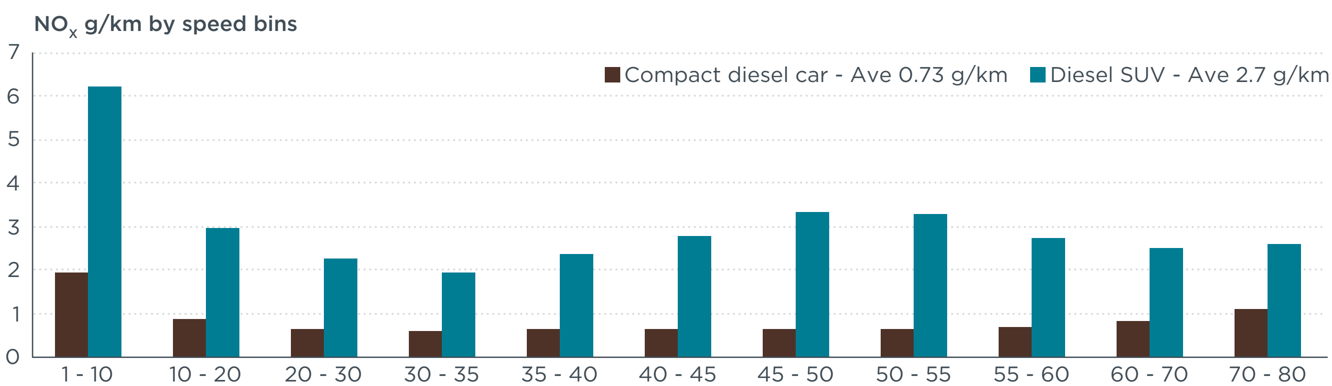

Figure 4. Distance specific NO_x emissions by speed bins. Idling emissions (V_{speed} <1 km/h) are not included. Average trip emissions are presented as a reference for each vehicle.

8 Ibid
9 Ibid

under those speed section that match the speed cut point criteria. The trip average is calculated by dividing the total mass of NO_x emitted by the total distance driven. Note that the RDE EU case is removed from the analysis as the driving style is not relevant to Indian driving conditions. The two proposed regulatory options deviate from the usual distance-specific emission behavior of diesel vehicles. The first regulatory option uses less than 5% of data to evaluate the motorway emission performance. The second option does not include any data point in the upper speed range. The newly proposed 30/50 km/h cut point generates speed distributions that more closely resemble the emission behavior presented in the previous figure. The urban driving section produces emissions about 20% higher than the average trip, while the motorway section is about 10% higher. For the diesel SUV, the AIS 137 proposed speed cut points do not produce results that align with typical diesel emission behavior. However, the 30/50 km/h cut points produce values that resemble typical diesel emissions, with higher urban and motorway emissions values than the trip average.

Based on these results, we recommend reducing the speed range definitions to better reflect Indian driving conditions for RDE testing. The data shows that defining the three sections with two cut points set at 30 km/h and 50 km/h results in time and distance distributions similar to those already in place for European RDE testing, while keeping the distance specific emissions within the expected behavior of diesel technology. Using higher speed cut points would result in non-representative data analysis and regulatory evaluation. Japan is also considering lower speed cut points 35/50 km/h as their driving style is slower than in Europe.[10]

Although the selection of language for lower speed cut points (30 km/h and 50 km/h) is not representative of typical urban, rural, and motorway driving, as urban driving in New Delhi covers speeds up to 50 km/h, retaining the three sections is a way to apply the

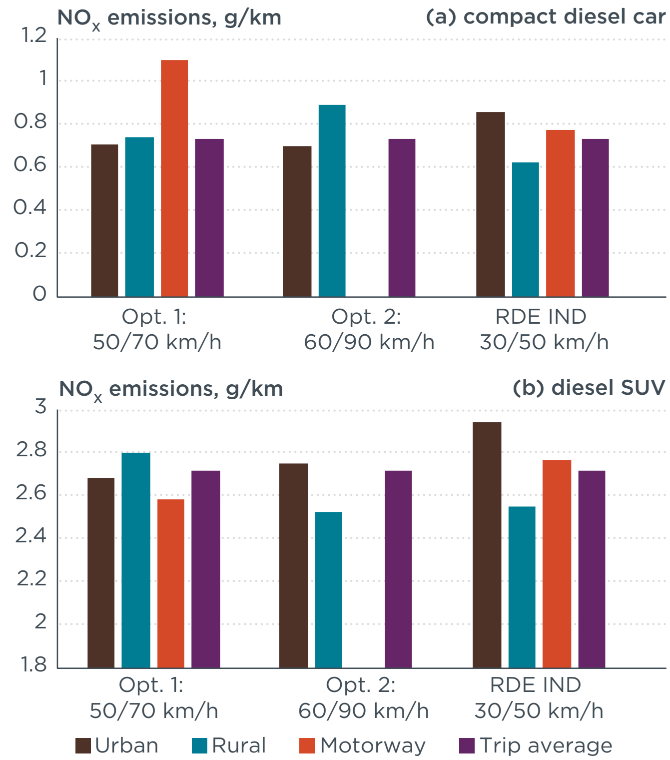

Figure 5. Distance specific NOx emissions binned by Urban, Rural and Motorway categories, for a diesel passenger car (a) , and for a diesel SUV (b)

mathematical formulation for other components of the original European RDE protocol. Indian RDE testing could alternatively incorporate a different language, such as low, medium, and high speeds, while retaining the three classifications structure. Another option for a two-section design, urban and extra-urban, could be proposed by avoiding the CO_2 characteristic curve, and evaluating the two sections independently.

REPORTING AND DISSEMINATION OF RDE TEST INFORMATION (ART 3.1.3)

The proposal to make emission test results available to the public is a step in the right direction. This idea is in agreement with international best practices regarding emissions and efficiency data sharing. Openly sharing data with the public is in the best interest of the manufacturers, as it provides confidence to costumers and research groups on the environmental performance of their vehicles. Without adequate disclosure, doubts about emissions performance of

10 Minister of Land Infrastructure, Transport and Tourism of Japan. *Development of the Japan's RDE (Real Driving Emission) procedure. Informal document GRPE-76-18 76th GRPE, 9-12 January 2018.* Retrieved from: https://www.unece.org/fileadmin/DAM/trans/doc/2018/wp29grpe/GRPE-76-18e.pdf

diesel vehicles will persist in public minds, and tarnish reputation of all diesel vehicles. U.S., European and Chinese vehicle manufactures are required to share the emissions certification and type approval results with the public.

The U.S. Environmental Protection Agency shares certification test details for light-duty vehicles and heavy-duty vehicles on their website. The certification data is updated annually and covers all models and engines sold for each model year. It includes general information such as the manufacturer and model name, technical characteristics of the vehicles such as engine displacement and rated power, and relevant emission test information. The emission test information covers dynamometer road load coefficient information and emission test results for each of the test required under U.S. federal regulations.[11]

Moreover, U.S. manufacturers of heavy-duty vehicle engines are required to report PEMS testing reports as part of the Heavy-Duty In-Use Testing requirements. At least 5% of all engine families are tested every year and the second-by-second PEMS data and results are made public.[12]

In the aftermath of Dieselgate, European authorities are developing new regulations that would add a level of transparency to emissions testing results to prevent a similar situation from occurring. The RDE results transparency measures are similar to what the current AIS 137 proposal is considering. In December 2016, China adopted the China 6 new light-duty vehicle emission standard regulation, which included a RDE regulatory component, and require that vehicle manufacturers publish the test results to the public.

Key recommendations to improve the current proposal are:

1. Change the information required to access the public RDE results. The current proposal asks for "*…entering the vehicle* ***type approval number*** *and the information on* ***type****,* ***variant*** *and* ***version****, the* ***unique identification number of a PEMS test family*** *to which a given vehicle emission type belongs…"* None of these 5 requirements are available to any party in India besides the manufacturer and the type approval authority, who already has access to the official RDE report.

   The only information required for any interested party to access the RDE results should be the manufacturer name, model year, model name, and variant (related to fuel type and engine displacement).

2. We recommend that the Ministry of Roads Transport and Highways (MoRTH) be in charge of collecting test results from test agencies, compiling the results, and updating a website for public access.

AMBIENT CONDITIONS (5.2)

Proper definition of what temperature conditions are considered moderate and extended is key for a realistic RDE evaluation in India. Emissions collected during "extended" environmental and driving conditions are subject to a correction factor to reduce the severity of emission levels recorded, as presented in Article 9.5. For extended conditions, the correction factor is 1.6; this means that emission rates measured are reduced by a factor of 1.6.

According to hourly temperature distributions for New Delhi taken from 1997 to 2017,[13] the moderate conditions, defined as at temperatures below 40°C, cover 96.5% of all hours (Figure 6 and less than 3.7% of all hours are below 10°C. We recommend retaining the proposed temperature definition.

The current proposal considers "extended" altitude conditions between 950 m to 1300 m. We recommend adding a "further extended" conditions covering 1300 to 2400 m, as is being done in China.

11 The reader can access the test certification files for LDVs and HDVs here: https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment

12 The reader can access those files here: https://www.epa.gov/compliance-and-fuel-economy-data/manufacturer-run-use-testing-program-data-heavy-duty-diesel-3

13 New Delhi hourly temperature data from https://www.kaggle.com/mahirkukreja/delhi-weather-data

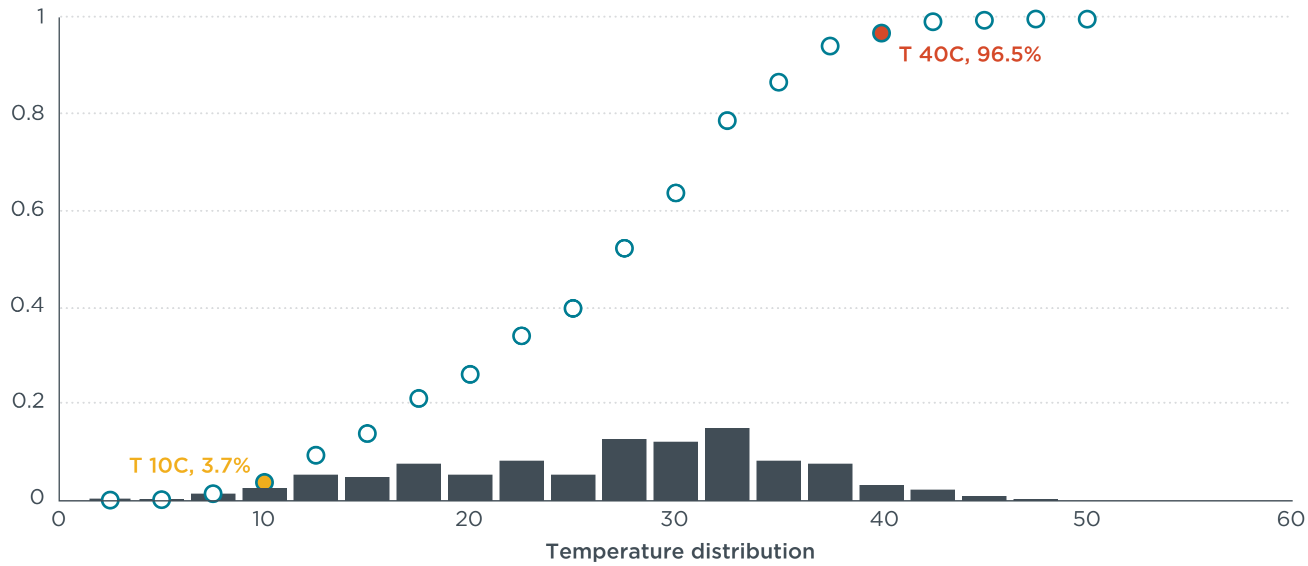

Figure 6. Hourly ambient temperature distributions for New Delhi 1997-2017. Source Kaagle.com

The Chinese RDE applies a 1.8 correction factor for these "further extended" conditions.

CALCULATION OF TOTAL NO_X EMISSIONS (APPENDIX 5 - SECTION 6.2 & SECTION 6.6)

In the current proposal, the weighing factors (f) defined for calculating NO_X compliance match those adopted in earlier EU RDE regulations, with a weight of 34/33/33% for the average windows NO_X emissions collected under urban, rural and motorway conditions, respectively. However, the latest EU RDE regulations changed the way the total NO_X emissions are determined. Under the earlier regulation, each of the thousands of average windows were evaluated for trip validity against a Worldwide harmonized Light vehicles Test Procedure (WLTP) CO_2 characteristic cure. Windows with CO_2 values above or below 30% the corresponding CO_2 characteristic curve value were filtered by a function (the *h* weighting factor) that reduced its value to 0 if the window's CO_2 deviation was beyond 50%. However, this method was abandoned for the 4th package as driving conditions that resulted in deviations from the CO_2 characteristic curve, such as by driving the car too smoothly or too dynamically, resulted in excessive window exclusions (weighted down to 0). Data evaluations performed by the Netherlands Organisation for Applied Scientific Research (TNO) showed that this function had an effect of downscaling raw emissions by 25%.

For the latest EU RDE regulations, the MAW method is still used to check the trip validity. Now, the way total emissions are evaluated has changed, and instead of weighting average windows average emissions as a function of a reference curve based on WLTP CO2 results, the new method use RDE CO_2 emissions as a proxy of the severity of the test. If RDE CO_2 emissions are 30% above the WLTP results, pollutant emissions are scaled down. We estimate that under the 4th package the downscaling of raw emissions would only be by -10%.

With urban air quality needing major improvements in several cities in India, it is important to adopt methods that ensure proper emission control operation and performance in urban driving conditions. Urban areas with low vehicle speeds (low-load operation) means lower-exhaust temperatures. Current selective catalytic reduction (SCR) based aftertreatment system technologies are highly active, with 80-99% NO_X reduction, only at higher operating temperatures above 180°C.

Proper selection of PEMS data evaluation methods will incentivize manufacturers to develop in-cylinder or EGR-based NO_X reduction strategies at low-load which the SCR system will not reduce.

Both methods retain the final compliance test that requires a dual evaluation for total and urban performance. Measured emissions are subject to independent comparison for total trip emissions, and also for urban emissions, against a not-to-exceed emission value, calculated as CF x emission limit. This ensures proper operation under urban driving conditions as well as overall performance.

We recommend the adoption of the Total NO_x emissions evaluation as presented in the EU RDE 4th regulatory package. This method provides closer results to real-driving raw emissions, while ensuring urban driving emissions are properly evaluated during RDE testing and addressed by manufacturers to meet those requirements. However, India would have an opportunity to improve this evaluation method and reduce the downscaling of emissions even further during the compliance evaluation.

RDE CONFORMITY FACTORS (SECTION 2.1.1)

Another element to consider in defining the conformity factor for India is the portable emissions measurement system uncertainty. The European RDE conformity factors for NO_x and PN were first adopted in 2015 as CF=2.1 for application in September 2017 and CF=1.5 from 2020. That covers the combined systemic deviations for all of the inputs used to measure emissions and data processing errors. Emission measurement elements include the sensors that measure concentration, exhaust mass flow, GPS and vehicle on-board diagnostics data for speed. Data processing elements cover time alignment and normalization. However, using extensive PEMS datasets, the Joint Research Center (JRC) of the European Union estimated that final RDE emission results would fall within +/- 30% of the true value. According to the European Commission (EC), the CF 2.1 value was an allowance for manufacturers to gradually adopt the RDE rules, while the CF=1.5 was a technical decision to account for PEMS measurement uncertainty.

As part of the 4th regulatory package, taking into consideration the improvements in sensing technology during the last 20 years of PEMS equipment development, the EC decided to reduce the CF from 1.5 to 1.43 for NOx, as a result of a revision of the PEMS measurement uncertainty. Research results by the EC had shown that the conformity factor could be as low as 1.24 for a NO_x limit of 80 mg/km.[14] An RDE test is compliant with the regulation if the reported distance-specific mass of emissions is below the respective Not-to-exceed (NTE) limit. The NTE has to be obeyed for both the total trip and its urban section, and is the product of the Euro 6 WLTC laboratory emission limit times the conformity factor of the respective pollutant. As a result, a RDE test will only be passed successfully if the NO_x emissions are below a threshold of 114 mg/km for diesel cars and 86 mg/km for gasoline cars. Note that for PN the CF remains at 1.5 after 2020.

Moreover, diesel technology manufacturers claim that they can provide low cost diesel technologies to reach very low NO_x emissions that are below RDE requirements. Bosch's engineers announced the reconfiguration of Euro 6 technology to be able to achieve real-driving emissions levels of 30-60 mg/km, well below the current standard.[15] Low real world emissions reductions are achieved via better engine-out NO_x controls and thermal management, using optimized turbochargers, low and high pressure EGR management, and thermal management by exhaust temperature regulation via injection delays and EGR calibration. All these technologies are currently available in Euro 6 passenger car technology, as well as in EPA 2007 and Euro VI heavy-duty technology, which means it has been applied for diesel vehicle emission control for the past 10 years.

Early this year, Daimler announced the adoption of real-world clean diesel technology for the whole spectrum of diesel variants, from the A- to the S-Class.[16] Daimler diesel engines of the new generation, such

14 Giechaskiel B., Clairotte M., Valverde V., Bonnel P., "Real driving emissions: 2017 assessment of Portable Emissions Measurement Systems (PEMS) measurement uncertainty," European Commission Joint Research Centre (JRC), May 2017. Retrieved from https://circabc.europa.eu/sd/a/c6054012-508c-4eb3-9cc2-728d2153f702/Margins%20NOx%202017%20report_v9c_public.pdf

15 "Breakthrough: new Bosch diesel technology provides solution to NO_x problem" Bosch Website, accessed May 30 2018. http://www.bosch-presse.de/pressportal/de/en/breakthrough-new-bosch-diesel-technology-provides-solution-to-nox-problem-155524.html

16 "State-of-the-art diesel technology from the A- to the S-Class: Latest Mercedes-Benz diesel technology with NO_x emissions significantly below certification limits" Daimler Global media site, accessed May 30, 2018. http://media.daimler.com/marsMediaSite/en/instance/ko/State-of-the-art-diesel-technology-from-the-A--to-the-S-Class.xhtml?oid=40361757&ls=L2VuL2luc3RhbmNlL2tvLnhodG1sP3JlbElk PTYwODI5JmZyb21PaWQ9NDgzNjI1OCZib 3JkZXJzPXRydWUmcmVzdWx0SW5mb1R5cGVJZD00MDYyNg!!&rs=5

as the OM 654, OM 656 and OM 60, already achieve average NO_x emissions of about 40 to 60 milligrams per kilometer on RDE journeys and in city traffic. These NO_x emissions are thus well below the current RDE limit of 168 mg/km and even below the laboratory limit of 80 mg/km. Organizations such as Dekra, TÜV and various auto magazines have confirmed that very good results are achieved in road tests, improved performance is expected. Daimler's goal is to arrive at average NO_x emissions of around 30 mg/km in RDE Stage 2 tests by 2020, and they are determined to achieve averages approaching 20 mg/km in the following years. Daimler is targeting these figures in particular for vehicles on European RDE driving tests in cities.

We recommend adopting a CF timeline that starts RDE implementation with CF= 1.43 for NO_x emissions in April 2023 and moves to CF= 1.0 by 2026. There is no need to wait for measurement accuracy improvements for PEMS equipment, as the same technology available today in Europe is being offered in India. Manufacturers will have to design their vehicles for real world emissions well below the CF levels, and the technology is already available, according to Bosch's engineers and proved by Daimler.

COLD ENGINE START (9.6 EMISSIONS AND TRIP EVALUATION)

Emissions during cold engine start conditions can contribute substantially to overall vehicle emissions, particularly in urban areas where trips are short, cold starts are frequent, and air quality problems are most severe.[17] Moreover, NO_x emissions during cold start could become a major contributor to the overall NO_x emissions of diesel cars once large parts of the diesel fleet are equipped with selective catalytic reduction (SCR) and lean NOx-trap after-treatment systems.

To get a sense of the impact of cold start emissions for diesel vehicles, we investigated the emissions results under cold start and hot start operation for 30 diesel vehicles in the U.S. The data comes diesel testing on the U.S. Federal Test Procedure (FTP-75) cycle. The FTP includes both a cold start, with the exhaust captured for analysis separately, and an engine restart after the engine has been shut off for 10 minutes, with the exhaust again captured for separate analysis. Both these test phases use exactly the same drive cycle. The vehicles included in the dataset are model year 2009 to 2015. On average, cold start NO_x emissions were 8 times higher than the average of hot start NO_x emissions.

The third European RDE package, adopted in December 2016, contains a procedure to include cold starts and regeneration events in the RDE test. Cold-engine start tests are expected to require the use of improved emissions control technology, especially for vehicles equipped with gasoline direct injection (GDI) engines. Because the urban driving emissions limit has to be met separately and includes the cold start, these new provisions are expected to substantially reduce emissions in cities where public exposure is greatest.

The European RDE 3rd and 4th packages still require the performance of a hot engine start RDE tests on a minimum number of vehicle families to prevent the activation of defeat-devices that use cold engine start as a flag for detecting laboratory and RDE testing.

We recommend adopting the European 3rd and 4th RDE package provisions that include cold start emissions as part of the regulatory evaluation. However, to prevent defeat device activation, we recommend the inclusion of a hot engine test on a minimum number of families to prevent defeat-devices using cold engine start as an indication for laboratory or RDE testing.

USE OF POWER BINNING METHOD (APPENDIX 6)

Until the third European RDE package, RDE trip validity was verified either by the MAW method or the Power Binning method. The MAW method takes into account the CO_2 distance-specific emissions during a trip, while the Power Binning method takes into account the power demand during a trip. Having

17 Windeatt, J., Brady, G., Usher, P., Li, H. et al., "Real World Cold Start Emissions from a Diesel Vehicle," SAE Technical Paper 2012-01-1075, 2012, https://doi.org/10.4271/2012-01-1075.

passed the validity test of one of those two methods was sufficient for the RDE test to count as valid.

With the introduction of the fourth European RDE regulation, the MAW method will become the only method for determining the validity of a RDE test. The Power Binning method was never fully adopted for regulatory application and is instead used for regulatory research. In China, Power Binning method was removed from the final RDE China 6 regulation. Thus, **we recommend** moving directly to the MAW method and dropping the Power Binning method and all references to it.

IN-SERVICE CONFORMITY AND MARKET SURVEILLANCE TESTING

In service conformity (ISC) testing refers to testing carried out by manufacturers on in-use vehicles and components to verify compliance to type-approval procedures. It is required of vehicle manufacturers throughout a vehicle's lifetime (in the United States, this is referred to as an in-use verification program/in-use confirmatory program, or sometimes in-use test). The ISC testing for light-duty vehicles (LDVs) in the EU essentially duplicates the tailpipe exhaust emission test conducted during type approval with the vehicle running on a chassis dynamometer in an emissions-testing laboratory.[18]

Market surveillance refers to independent verification testing and inspection carried out by regulatory authorities on in-use vehicles and components to determine whether they continue to comply with exhaust emissions standards (in the U.S., this is referred to as in-use surveillance testing/in-use confirmatory testing or in-use surveillance). For purposes of market surveillance, regulators need not be bound only to repeat the test procedure used for type approval, but could put a vehicle through other tests not specified in advance, either in the laboratory (e.g., running the vehicle over alternate driving cycles) or on the road.

In the case of India, ISC is part of the application process for type approval of Bharat VI vehicles under the proposed Bharat VI regulation. However, the proposed In-Service Conformity provisions only mandate a "Type I" test for tailpipe emission verification, that means duplicating the chassis test carried out during type approval. In addition to this, there is not a formal structure to verify the CO_2 emissions data neither under Type I nor under PEMS testing.

As part of the 4th RDE package in Europe, it was decided to introduce a minimum level of ISC checks[19] of vehicles to be performed by the granting type-approval authority. Today, ISC checks are entirely in the hands of car manufacturers only, and they are only carried out for air pollutant emissions, not for CO_2. This responsibility will shift to the respective type-approval authorities. The granting type-approval authority must gather all relevant information on possible emission non-compliances relevant for deciding which ISC families to check in a particular year. The number of compulsory annual ISC checks level is set to 5% of PEMS families or a minimum of two families per manufacturer. This is significantly lower than the 20% of PEMS families that stakeholders, such as environmental NGOs, were originally asking for.[20] In addition to the granting type-approval authorities, ISC checks can be performed by other type approval and mandated accredited laboratories.

The China 6 RDE regulation introduces a comprehensive in-use compliance program. Manufacturers are required to test in-use vehicles at low (10,000–60,000 km), medium (60,000–110,000 km), and high (110,000–160,000 km) mileages and report their test results to the regulatory agency. The regulatory agency has the authority to randomly test in-use vehicles up to 160,000 km of driving.

18 Zifei Yang and Rachel Muncrief. *Market surveillance of vehicle emissions: best-practice examples with respect to the European commission's proposed type-approval framework regulation.* (ICCT: Washington DC, 2017). https://www.theicct.org/sites/default/files/publications/PV-in-use-surveillance_ICCT-position-brief_13072017_vF.pdf

19 In comparison to ISC checks, the scope of European market surveillance testing - as introduced by the revised type approval framework directive, is wider, including not only emissions but also safety testing, making use not only of laboratory and PEMS testing but also remote sensing as well as on-board measurements. Market surveillance checks can also serve as a pre-screening of vehicle models that will then be selected for more in-depth ISC testing.

20 Transport and Environment T&E (2018). *Letter to TCMV members: European Commission's proposal regarding the RDE 4th package & WLTP 2nd act*. Transport & Environment. April 2018. Retrieved from https://www.transportenvironment.org/sites/te/files/publications/2018_04_TE_letter_TCMV_members_vote_for_RDE_4_and_WLTP_2.pdf

We recommend, as a first step, adopting PEMS based tests as part of the In-Service Conformity regulation for passenger vehicles in India, and moving later to developing the regulatory framework for adopting a Market surveillance program that places the testing responsibility in the type-approval authority. This will imply developing the required technical capacity. Manufacturer data would still be required but only as a way to screen for potential ISC tests subjects.