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Review Report

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Indian Drive Cycles and RDE Program for Effective Emission Norms, Controls and Policies

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Abstract

India is the fifth-largest global car manufacturer in 2019, with one of the highest compound annual growth rates of vehicle registration at 10 percent. The automotive sector will continue to grow rapidly because of the economic growth, prosperity, and continued aspiration of vehicle ownership. It is projected that by 2030 the annual car sales in India will increase from the current 3.5 million to about 10.5 million. Vehicles annually contribute about 290 Gg of PM2.5 (particles of size less than or equal to 2.5 µm) and about eight percent of annual GHG emissions. India has to plan today on how to tackle vehicular emissions. Improvements in automobile technology, fuel efficiency, quick transformation to improved emission control technology, and stringent emission norms are prerequisites for vehicle emission controls.

The IDC (Indian Driving cycle) was the first driving cycle formulated for vehicle certification for emissions and safety. The IDC is a short cycle comprising six driving cycles modes of 108 seconds. The IDC does not cover the complex driving conditions observed on the Indian roads. The average speed of IDC is 21.9 km/h (covering 3.94 km), which is high in congestion cities and low for rural roads or highways. The IDC considers only gentle accelerations (<0.65 m/s^2), and relatively low engine loads. IDC allows preconditioning idling time (other than diesel vehicles) of 40 seconds before the chassis dynamometer test is performed, thus ignoring the cold start.

As an improvement over IDC, MIDC (modified Indian drive cycle) was adopted, which is equivalent to the New European Driving Cycle (NEDC). MIDC accounts for wider speed profiles. MIDC is also significantly close to the idling conditions observed in real-world driving. The maximum speed in the MIDC cycle is set to 90 km/h.

Despite the improvements, MIDC may not accurately assess vehicle emissions during on-road conditions because of variations in traffic density, land-use patterns, road infrastructure, and poor traffic management. In addition, the acceleration profiles in the cities vary significantly from the prescribed acceleration in MIDC. The realistic speed-acceleration profiles are considerably higher than that mandated in MIDC. In high power requirement zones, i.e., the accelerations and decelerations are not well reflected in the MIDC. In such conditions, vehicles emit high NOx and other pollutants.

The Worldwide Harmonized Light Vehicle Test Procedures (WLTP), is a global harmonized standard for determining the levels of pollutants of traditional and hybrid cars. It is prudent that India adopts WLTP and a suitable cycle or equivalent procedure for a wider range of driving conditions similar to those of other countries.

The European Commission, USA, and China suggest that the driving cycles and laboratory tests do not reflect the likely emissions during real driving conditions, which are more complex than laboratory driving cycles. Real driving emissions (RDE) test, an independent test to overcome the limitations of WLTP and equivalent laboratory tests, is widely used. For RDE test, a car is driven on public roads over a wide range of conditions. Portable Emission Measurement System (PEMS) is installed on the vehicle that collects data to verify legislative caps for pollutants such as NOx, particle number (PN), etc. RDE tests are slowly becoming mandatory in many countries.

The Indian agency, International Centre for Automotive Technology, is currently developing RDE procedures that are likely to come into force in 2023. The RDE cycle must cleverly account for conditions prevailing in the country, such as low and high altitudes, year-round temperatures, additional vehicle payload, up and downhill driving, urban and rural roads, and highways. In this context, the following points come to the fore to make the Indian RDE program robust and in accordance with Indian conditions:

- The motorable altitude is in the range of MSL to 3500 m. Most vehicles' common range for altitude is expected to be MSL to 1300 m, excluding the hilly areas. The India RDE should extend altitude limits up to 2400m above MSL.
- India has a large area with a significant time span of near and sub-zero temperature zones in the winter months. The lower temperature limits should extend to 0°C.
- India is using MIDC for type approval which is far from international laboratory testing cycles. Therefore, India should shift to WLTP.
- The Indian market has highly efficient multi-point fuel injection (MPFI) diesel vehicles and such vehicles can achieve lower PN/PM emissions with tail pipe emission control devices. Therefore, the PM/PN limits can be further tightened in heavy-duty diesel vehicles.
- India needs to define conformity factors (CFs) for RDE testing, which should be comparable to international counterparts and meeting Indian requirements. EU has implemented CFs at 1.5 (NOx and PN) level for EURO-6b. In due course of time, the emission limits during RDE should become fuel neutral.
- Emission control can be achieved via after combustion emission control technologies, like catalytic converters and particulate filters.
- Road maintenance and marking, smart traffic signaling, the standard design of the speed breakers, speed warnings and traffic discipline are important contributors to RDE. They should be optimized on urban, rural roads and highways.

- Poor quality lubricants and their inappropriate recycling is an important cause of higher RDE. The quality of lubricants should improve and recycled unorganized sale of the lubricants should be stopped.

The Government of India has launched the Vehicle Scrappage Policy on August 13, 2021. The purpose of the Vehicle Scrappage Policy is to phase out old and inefficient vehicles and recycle them through a well-structured system. This policy will reduce air pollution caused by old vehicles that have surpassed their lifecycle and are not roadworthy. The benefits of Vehicle Scrappage Policy 2021 include;

- 4-5% Showroom price will be given as cash return;
- Tax rebate will also be given up to 25% for new vehicle registration; and
- Showrooms and dealers will also give discounts on showing scrappage certificates of old vehicles.

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Indian Drive Cycles and RDE Program for Effective Emission Norms, Controls and Policies

1 On-road vehicular emission regulations in India

Automobiles, powered by internal combustion engines, are the primary means of transport for man and material. These engines use fuels (like gasoline, diesel, ethanol, biodiesel, CNG, PNG, etc.) to convert chemical energy into mechanical energy. The conversion process consists of the burning of fuel to produce energy. The burnt products come out in the form of pollutants (like CO_2, NO_2, N_2O, NO, CO, aromatics, and toxic metals and particulate matter (PM; primarily measured as particle number (PN) in a specified volume of exhaust). Emissions are a major health concern, especially in urban areas. More than 90 percent of the world's population is exposed to air pollution concentrations that exceed the World Health Organization (WHO) guidelines (Warren, 2018). Globally, an estimated 4.5 million people died prematurely from exposure to PM and ozone pollution in 2015 (Fuller, 2019), where the contribution of vehicles emission is significant.

India is the fifth-largest global car manufacturer in 2019, with one of the highest compound annual growth rates (CAGR) of vehicle registration at 9.9% between 2006 and 2016 (*Road Transport Year Book, 2015-16*, 2018). Cars and two-wheelers constitute about 87% of the total vehicle population (*Road Transport Year Book, 2015-16*, 2018). In India, vehicles contributed about 290 Gg of $PM_{2.5}$ (particles of size less than or equal to 2.5 um) in 2016 (Maddhesia, 2020). In urban areas, the vehicle contribution of $PM_{2.5}$ concentration can exceed 25 % of the total $PM_{2.5}$ concentration(Maddhesia, 2020). Around 30% of total GHG emissions in Delhi are from vehicles (Nagar et al., 2019).

The automotive sector will continue to grow rapidly because of the economic growth, prosperity, and continued aspiration of vehicle ownership. It is projected that by 2030 the annual car sales in India will increase from the current 3.5 million to about 10.5 million and similar growth in other automotive segments will be observed (Ghosh, 2020). India has to plan today on how to tackle vehicular emissions. Improvements in automobile technology, fuel efficiency, quick transformation to improved emission control technology, and stringent emission norms are prerequisites for India.

Most countries formulate a regulatory framework at the manufacturing end and while the vehicles are in use (discussed later). The regulatory framework necessitates the development of protocols and infrastructure for testing vehicle emissions. There are two central agencies, the Automotive Research

Association of India (ARAI[1]), Pune and the International Centre for Automotive Technology (ICAT[2]) under the aegis of National Automotive Testing and R&D Infrastructure Project (NATRiP[3]), Government of India. These agencies are entrusted with certifying the emission compliance of the vehicles before the vehicle can come into the market.

The European Commission, USA, and China suggest that the driving cycles and laboratory tests do not reflect the likely emissions during real driving conditions, which are more complex than laboratory driving cycles (Chong et al., 2018; Giechaskiel, 2018; Giechaskiel et al., 2021). In the real driving emissions (RDE) tests, a car is driven on public roads over a wide range of conditions. Equipment is installed on the vehicle that collects data to verify legislative caps for NOx pollutants. RDE tests are slowly becoming mandatory.

After April 2020, the stringent emission norms and forthcoming RDE norms (from April 2023) put Indian original equipment manufacturers (OEMs) to achieve the stringent norms. Because India is committed to international collaborations towards reducing harmful emissions, India must implement or make the right policies to conduct RDE tests and achieve the norms. In this IIT Kanpur report, we objectively discuss the following points:

- A brief review of the historical evolution of emission norms with Indian perspective and critical learning points;
- Present emission norms, their limitations and shortcomings and implementation procedures. Some critical issues on worldwide harmonized light vehicle test cycle (WLTC) and modified Indian driving cycle (MIDC);
- Future RDE norms, in-service conformity, requirements for a successful RDE cycle (like temperature, RH, altitude, etc.), policy design and enforcement, and need of RDE package 4 over 3;
- Fuel neutral emission norms (primarily for PN and NOx); and
- Vehicle scrapping policy of India.

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[1] ARAI is the leading automotive R&D organization of the country set up by the Automotive Industry with the Government of India. ARAI is an autonomous body affiliated to the Ministry of Heavy Industries and Public Enterprises, Government of India. ARAI is one of the prime Testing and Certification Agency notified by Government of India under Rule 126 of Central Motor Vehicle Rules, 1989. ARAI is certified to ISO 9001, ISO 14001, ISO 27001 and ISO 45001; and is also accredited for its testing and calibration scope as per ISO/IEC 17025 by National Accreditation Board for Testing and Calibration Laboratories (NABL). Web link (https://www.araiindia.com/)

[2] ICAT is providing quality services to the industry in all the domains of automotive and non-automotive development, such as Powertrain, Noise Vibration and Harshness, Component, Fatigue, Photometry, Tyre & Wheel, Passive Safety, EMC and CAD & CAE. Web link (https://icat.in/)

[3] NATRiP aims at creating core global competencies in automotive sector in India by facilitating seamless integration of Indian Automotive industry with the world, through setting up state-of-the-art, four green field automotive testing, homologation and R&D infrastructure facilities and up-gradation of two existing facilities with new technology and equipment

1.1 Vehicle Emission standards

The common sources of automotive emission standards and protocols are the USA, European Union (EU) and Japan; other countries derive their emission norms based on the regulation prevailing in these three countries/consortia. India bases its norms on the EU. The Indian standards are called Bharat Stage (BS), which maps to Euro norms (e.g., BS-IV maps to EURO-4). The timeline of Indian automobile standards is shown in **Figure 1**. The BS-VI limits for passenger cars and 2-3-wheelers are given in **Table 1**. Currently, Indian certifying agencies conduct Real-driving Emissions (RDE) for BS-VI vehicles and analyze the data for formulating RDE regulation.

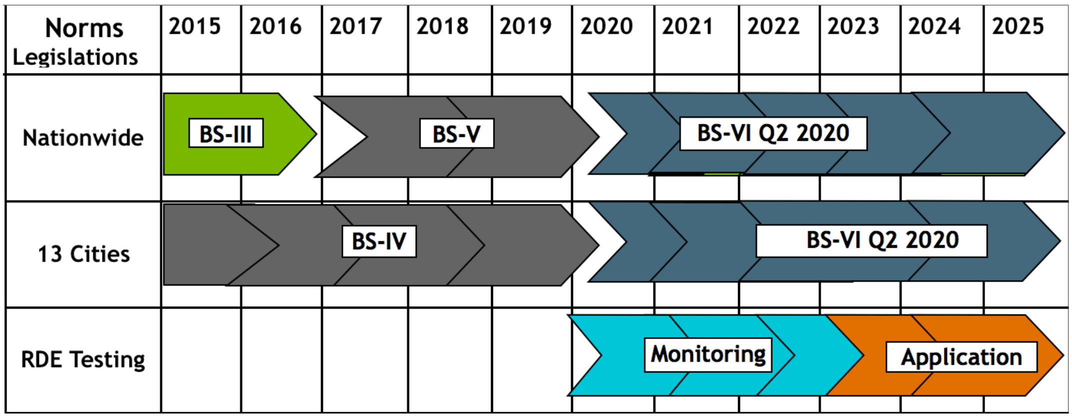

Figure 1: BS-VI norms timeline (Sawangwong, 2019)

Table 1: BS-VI Emission Standards for Passenger cars and 2-3 Wheelers (*GSR 889(E)*, 2016)

Vehicle	Emissions limits in gm/km				
	CO	HC	NOx	PM	PN/km
Gasoline Car	1.0	0.1	0.06	0.0045	6.0×10^{11}
Diesel Car	0.5	NA	0.08	0.0045	6.0×10^{11}

In 2016 (**Figure 1**), the Indian Government took steps to skip the BS-V norms and leapfrog to BS-VI norms by 2020. This massive scaling is a unique effort in the world; no other country has done it before. Refineries and automobile manufactures have achieved monumental feet within a short time to produce fuel and vehicles compliant with BS-VI. India joins the US, Japan and the EU to achieve BS-VI (equivalent to EURO-6) norms. The country has invested an estimated 15 bn USD (i.e., Rs. 100,000 crores (Dalvi & Dhingra, 2019)) for becoming BS-VI compliant. Citizens and Original Equipment Manufacturers (OEMs) will be more responsible for maintaining the BS-VI vehicles properly. There must be a regulatory mechanism to maintain desired emission norms throughout the vehicle's life; otherwise, it would mean forfeiting massive investment benefits and underperforming the technology.

Sizeable numbers of old vehicles should be replaced quickly to pave the way for BS-VI vehicles. The vehicle scrapping policy will be crucial in how fast India can hasten the entry of new BS-VI vehicles.

1.2 Emission Certification and Driving Cycle

1.2.1 India

The Ministry of Road Transport, Highways & Shipping (MoRTHS; https://morth.nic.in) acts as the nodal agency for formulating and implementing various provisions of the Motor Vehicle Act. The Motor Vehicles Act (MVA), 1988 and the Central Motor Vehicles Rules (CMVR[4]) are the vital governing regulations for vehicle emissions. The key points for approval of vehicles and engines for Type Approval[5] and Conformity of Production (COP[6]) include:

- The manufacturer is responsible for completing COP before the end of the COP period for each model and each fuel type produced at the different production plants; and
- During COP, emission measurement on the vehicle using PEMS shall be carried out for data collection and future RDE regulation.

ARAI and ICAT are the India's premier Homologation and Testing centers for "Type Approval Certificate (TAC)" and "Conformity of Production (COP) Certificate," including compliance with emission regulations.

The vehicle certification procedures consist of testing engine performance and emission compliance on the engine and/or chassis dynamometer in the laboratory. A driving cycle is followed to achieve the rightful and acceptable test results, which should nearly simulate the realistic driving intended for the vehicle type. A driving cycle is a series of continuous data points comprising the speed of a vehicle and time.

Indian Drive Cycle (IDC)

The IDC was the first driving cycle based upon extensive road tests. The IDC is a short cycle comprising six driving cycles modes of 108 seconds (**Figure 2**) (Sharma et al., 2013). The IDC does not cover the

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[4] In India, the rules and regulations related to driver's license, registration of motor vehicles, control of traffic, construction & maintenance of motor vehicles, etc. are governed by the Motor Vehicles Act (MVA),1988 and the Central Motor Vehicles Rules (CMVR), 1989.

[5] Type approval or certificate of conformity is granted to a product that meets a minimum set of regulatory, technical and safety requirements. Generally, type approval is required before a product is allowed to be sold in a particular country.

[6] COP is a means of evidencing the ability to produce a series of products that exactly match the specification.

complex driving conditions observed on the Indian roads. The average speed of IDC is 21.9 km/h (covering 3.94 km), which is high in congestion cities and low for rural roads or highways, only gentle accelerations (<0.65 m/s^2), and low engine loads (Sharma et al., 2013) are included. IDC allows preconditioning idling time (other than diesel vehicles) of 40 seconds before chassis dynamometer test is performed (MoRTH, 2000), thus ignoring cold start. Because of the above limitations, IDC does not represent real-world driving and is likely to underestimate the emissions.

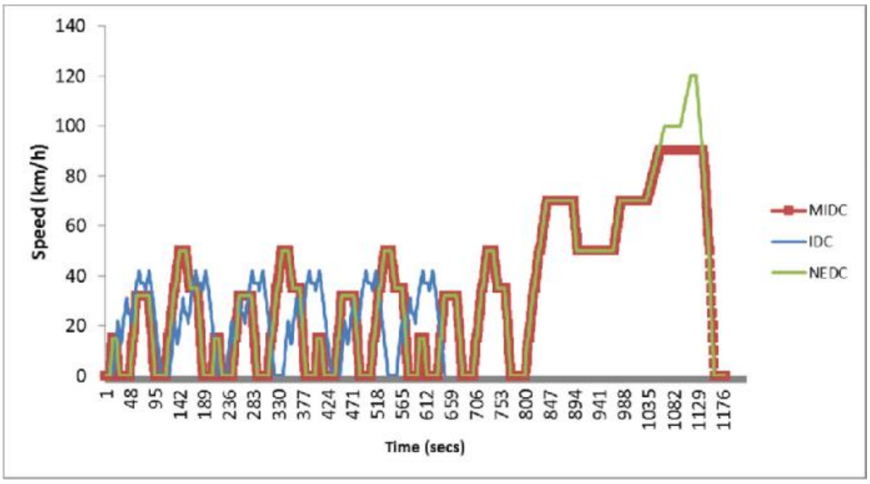

Figure 2: Speed vs Time profile of drive cycles IDC in India

Modified Indian Drive Cycle (MIDC)

MIDC was adopted in the year 2000 and was later modified with a better cold start testing procedure. This cycle is generally the same as the New European Driving Cycle (NEDC) (**Figure 2**) (Sharma et al., 2013). MIDC accounts for wider speed profiles and hence it is a better-suited cycle than the IDC. MIDC is also significantly close to the idling conditions observed in real-world driving. The maximum speed in the MIDC cycle is set to 90 km/h. Despite the improvements, (Chugh et al., 2012)) suggest that MIDC may not accurately assess vehicular emissions during on-road conditions because of variations in traffic density, land-use patterns, road infrastructure, and poor traffic management.

Further, the acceleration profiles in the cities vary significantly from the prescribed acceleration in MIDC (Figure 3). The realistic speed-acceleration profiles are considerably higher than that mandated in MIDC. In high power requirement zones, i.e., the accelerations and decelerations are not well reflected in the MIDC. In such accelerations and decelerations, vehicles emit high NOx and other pollutants (Huang et al., 2013 and Chen et al., 2007).

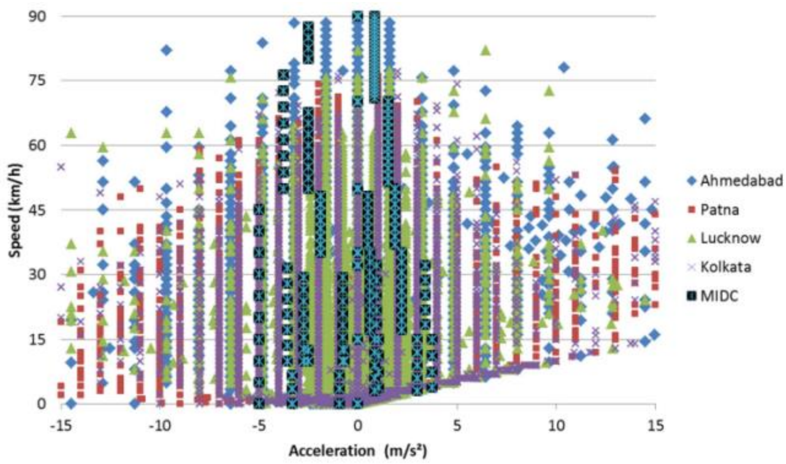

Figure 3: Speed vs Acceleration profile of MIDC and RDE in few Indian cities (Sharma et al., 2013)

1.2.2 Worldwide Harmonized Light Vehicle Test Cycle (WLTC)

To address the limitations of the new European drive cycle (NEDC), a new procedure, Worldwide Harmonized Light Vehicle Test Procedures (WLTP), has been formalized by UNECE (ECE/TRANS/WP.29/GRPE/2020/14). The WLTP is a global harmonized standard for determining the levels of pollutants, CO_2 emissions and fuel consumption of traditional and hybrid cars and the range of fully electric vehicles.

Within WLTP, there are several cycle classes have been developed (e.g., WLTC 1, WLTC2, WLTC3) by the UNECE GRPE (Working Party on Pollution and Energy) and published as UNECE Global technical regulation No 15 (GTR 15). Sequentially these cycles represent speed profile to meet specific local requirement. Speed and acceleration profiles of WLTC3 are shown in Figure 4 and Figure 5. Some salient features of WLTC are briefly described.

- Higher average and maximum speeds;
- A wider range of driving conditions (rural, suburban, urban, highway);
- Simulates a longer distance;
- Higher average and maximum drive power; and
- Steeper accelerations and decelerations.

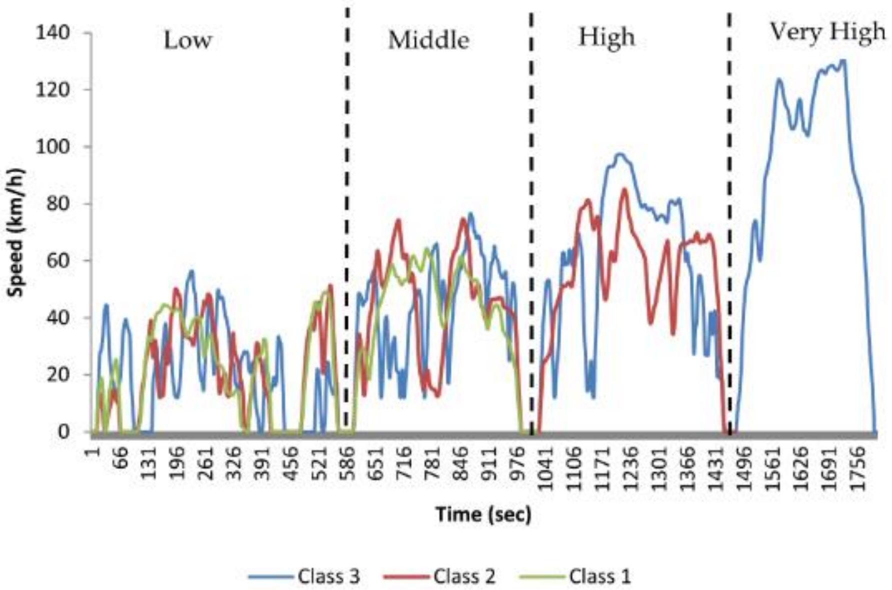

Figure 4: WLTP 1, 2, 3 Comparison speed profile (Sharma et al., 2013; Tutuianu et al., 2013)

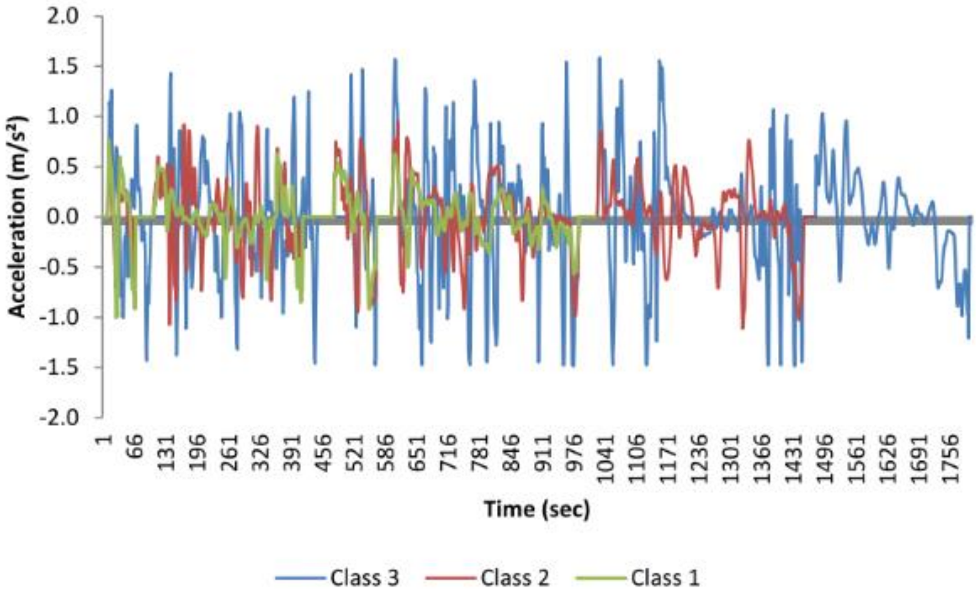

Figure 5: WLTC3 Acceleration profile (Sharma et al., 2013; Tutuianu et al., 2013)

In **Figure 6**, acceleration range versus speed profile of WLTC3 is compared with the profile of MIDC. WLTC3 covers larger variations in speed and acceleration.

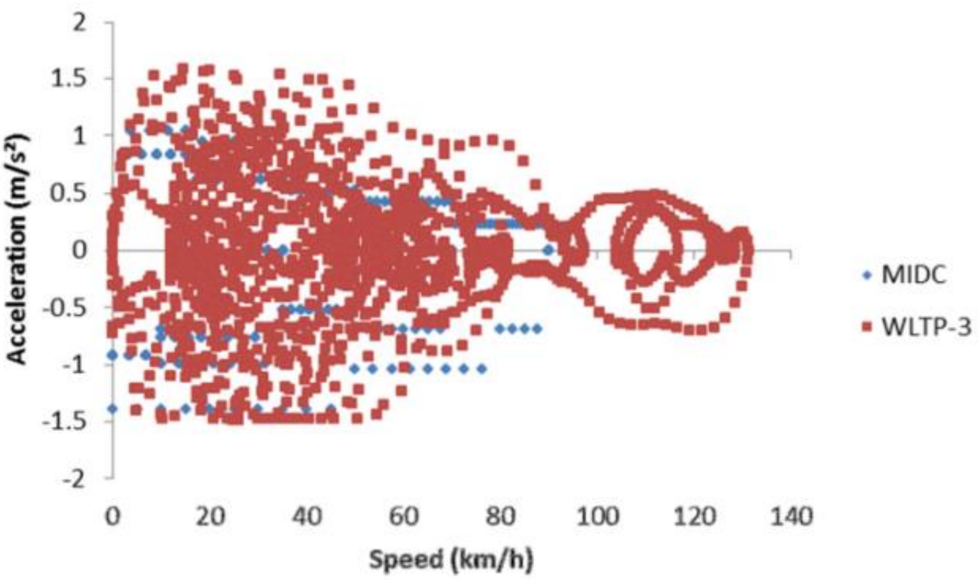

Figure 6: Speed vs Acceleration profile of MIDC and WLTC3 (Sharma et al., 2013; Tutuianu et al., 2013)

With more dynamic driving conditions (higher maximum velocity and a smaller share of idling time), WLTC can be considered as realistic driving cycle that can better represent actual on-road vehicle emissions, even though it is still a laboratory cycle with predefined ambient conditions and no road gradient (Gong et al., 2017).

1.2.3 US Federal Test Procedure

The Federal Test Procedure of USEPA, FTP-75 is the city driving cycle representing a series of tests to measure passenger cars' tailpipe emissions and fuel economy. The current procedure has been updated and it includes four tests: city driving, highway driving, aggressive driving, and optional air conditioning test.

The city-driving program of the USEPA Federal Test Procedure is shown in Figure 7. The cycle has the following features (US EPA, 2015)

- Distance travelled: 17.77 km
- Duration: 1874 seconds
- Average speed: 34.1 km/h

It may be noted that the first 505 seconds for cold start, second transient phase 864 seconds and the third phase of 505 seconds for a hot start (identical to cold start).

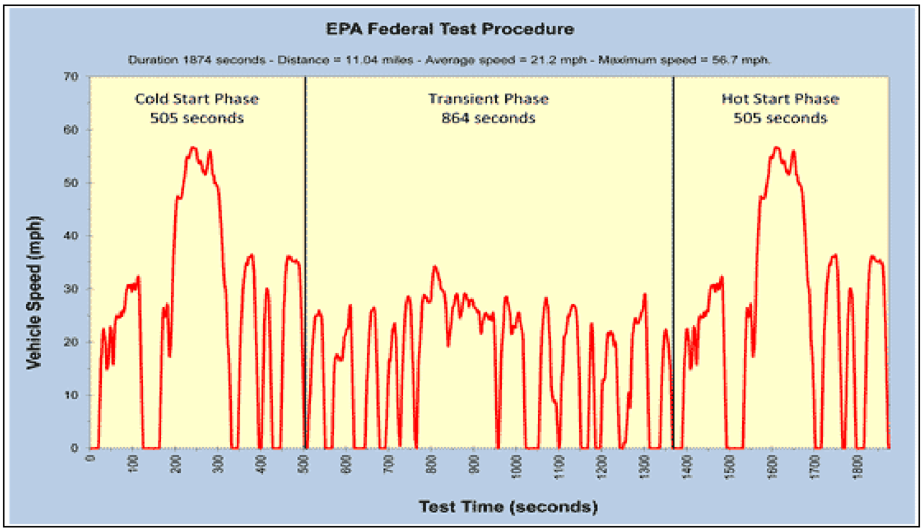

Figure 7: The Federal Test Procedure (FTP75)

The California Unified Cycle (UC) is a dynamometer driving schedule for light-duty vehicles developed by the California Air Resources Board. UC is a more aggressive driving cycle than the federal FTP-75; it has higher speed, higher acceleration, fewer stops per mile, and less idle time. EPA New York City Cycle (NYCC) test has been developed for chassis dynamometer testing of light-duty vehicles (Office of the Federal Register, 2016, p. 86). The test simulates low-speed urban driving with frequent stops.

1.2.4 China Light-Duty Vehicle Driving Cycle (CLDC)

China adopted the New European Driving Cycle (NEDC) as the test cycle for China-I to China-V emission norms (Liu et al., 2020). To test how well the WLTC represents driving conditions in China, driving cycles in 20 representative cities with different city scales, altitudes, locations and terrain were tried. WLTC resulted in higher fuel consumption than NEDC and there was also a smaller difference in the fuel consumption between WLTC and the real road at about 14.0% compared to about 22.5% between NEDC and real road fuel consumption (Wu et al., 2017). Based on the collected data, China developed a China Light-Duty Vehicle Driving Cycle (CLDC) and compared the characteristics with the WLTC (Figure 8).

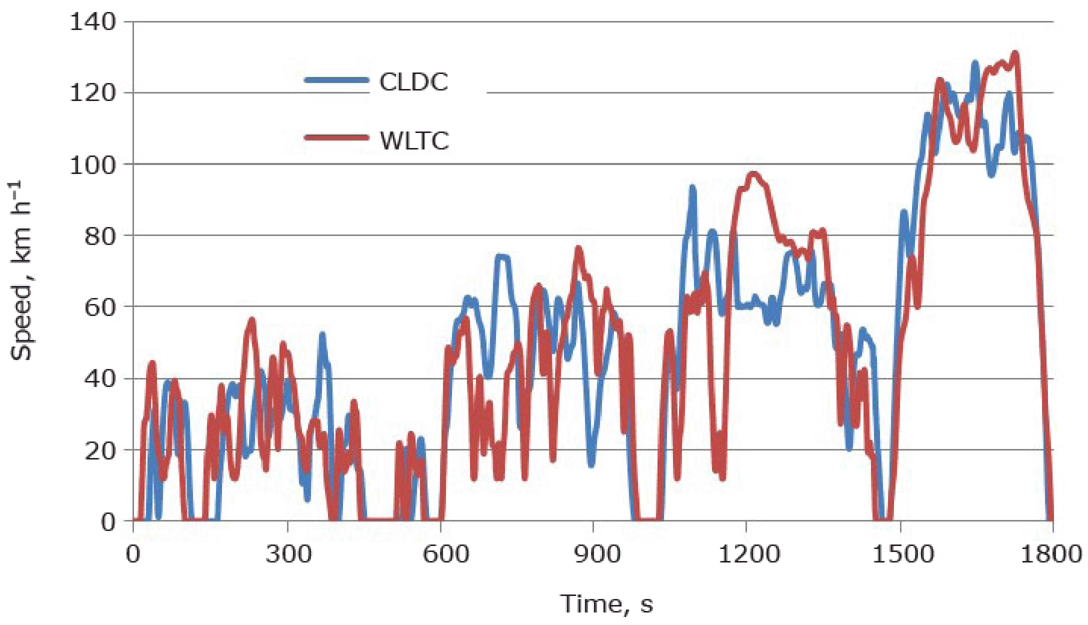

Figure 8: Speed profile of WLTC and CLDC (Liu et al., 2020)

The CLTC shows the highest coincidence with real driving data from China featured with a low average speed, a high idle ratio and more frequent acceleration and deceleration (Liu et al., 2020). CLDC adequately represents real-world fuel consumption for Chinese conditions (Liu et al., 2020).

1.2.5 Japan

Japan's 2005 emission regulation introduced a new JC08 chassis dynamometer test cycle for light vehicles (< 3500 kg GVW[7]) (*Final Report of Joint Meeting between the Automobile Evaluation Standards Subcommittee*, 2011). The test represents driving in congested city traffic, including idling periods and frequently alternating acceleration and deceleration. Measurement is made twice, with a cold start and with a hot start. The test is used for emission measurement and fuel economy determination for gasoline and diesel vehicles. The JC08 test had been fully phased in by October 2011. In the transitional period, emissions were determined using weighted averages from different cycles:

- 2005.10: 12% of 11 mode cold start + 88% of 10-15 mode hot start;
- 2008.10: 25% of JC08 mode cold start + 75% of 10-15 mode hot start;
- 2011.10: 25% of JC08 cold start + 75% of JC08 hot start.

[7] Gross Vehicle Weight

The JC08 driving schedule is schematically shown in Figure 9.

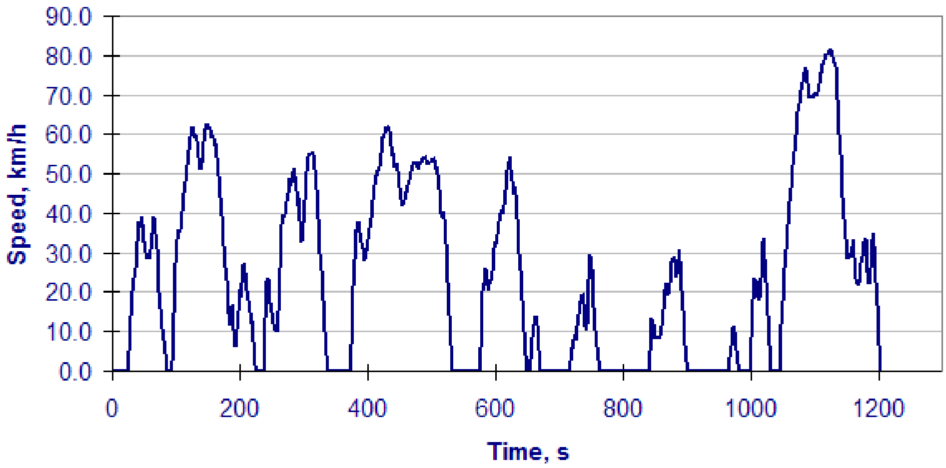

Figure 9: JC08 Test Cycle

After 2018, the WLTP was introduced for vehicle certification in Japan (New type-approved passenger cars and light trucks with GVW < 3.5 t) (*Final Report of Joint Meeting between the Automobile Evaluation Standards Subcommittee*, 2011).

In summary, the UNECE World Forum for Harmonization of Vehicle Regulations (WP (working party).29) is the worldwide forum in which relevant stakeholders and countries from the world participate. The UNECE facilitates a legal framework allowing establishing internationally harmonized regulatory framework concerning the certification of motor vehicles including emissions. The WLTP and WLTC developed in collaboration with UNECE have been adopted by many countries with minor modifications to suit their local conditions. In 2016, the Worldwide Harmonized Heavy-Duty test Cycle (WHDC) was introduced to the regulations for trucks and buses (ECE/TRANS/WP.29/2016/69, (Dagan, 2012)). India is still using the MIDC. MIDC does not account fully for the acceleration profiles, which vary significantly from the prescribed acceleration. MIDC covers lower maximum speed and shorter time for the driving cycles. It is prudent that India adopts WLTP and suitable cycle or equivalent procedure to have a wider range of driving conditions similar to those prescribed by other countries. Timeline of different testing cycles is given in Figure 10.

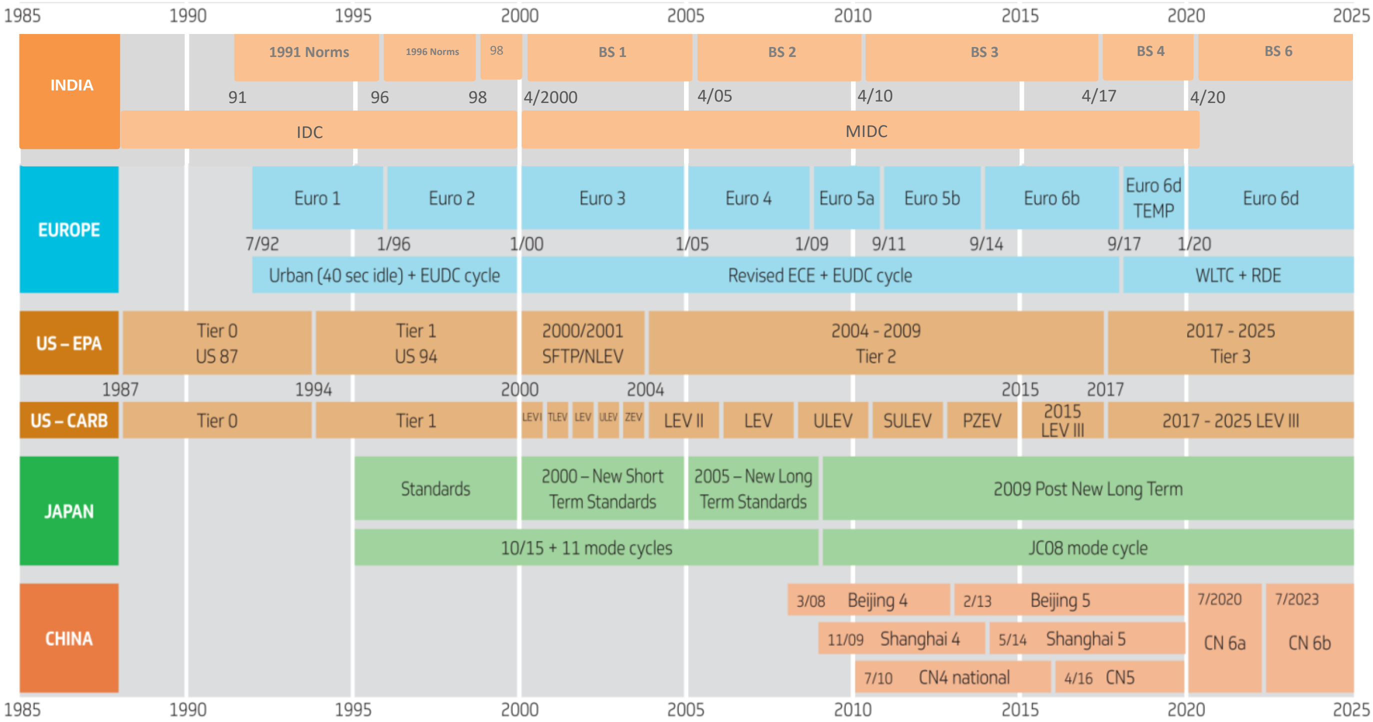

Figure 10: Timeline of Toxic emission standards and Chassis dynamometer test cycles (*Worldwide Emissions Standards Passenger Cars and Light Duty Vehicles*, 2021)

1.3 Real Driving Emissions: Need and Challenges

A few countries, European Commission, USA, and China, had questioned the driving cycles and laboratory tests if they did reflect the likely emissions during real driving conditions, particularly nitrogen oxides (NO_x) (Chong et al., 2018; Giechaskiel, 2018; Giechaskiel et al., 2021). Serious concerns have emerged in the last few years over the emission performance of diesel cars in real-world driving conditions (Franco et al., 2014; Quiros et al., 2016). There is room for the engine manufacturers to exploit the limitations of the existing test cycles by optimizing their engine management systems to comply with the emission norms only at specific test points covered by the cycle; leading to increased emissions under real-world operation. The existing regulatory and testing protocol (e.g., NEDC) for EURO-5 and EURO-6 vehicles could not address real-world road emissions. Consequently, RDE tests are becoming mandatory.

The challenge in RDE tests is the trip (speeds, distances, durations, etc.) selection that can offer a RDE driving cycle. The EU has formalized the RDE driving cycle (Commission Regulation (EU) 2016/427) concerning overall traffic, road, and physical ambient conditions (Commission Regulation (EU) 2016/646) (Donateo & Giovinazzi, 2017).

2 RDE Regulations and Adoption in India

RDE is an independent test to overcome the limitations WLTP and equivalent laboratory tests. Under RDE, a car is driven on public roads and over a wide range of different conditions. Specific equipment installed on the vehicle collects the data to verify that legislative caps for pollutants such as NOx and PN in real traffic. Europe is one of the first regions to introduce such on-road testing, marking a major leap in the testing of vehicle emissions. The following conditions affect the RDE and the RDE test procedures should include these conditions for a justified and accepted procedure.

2.1 Technical review of ambient and other conditions for RDE procedures

RDEs are affected by ambient temperature, pressure, humidity, road conditions, altitude, fuel composition, engine technology, the resistance between vehicle parts, OBD (On-board diagnostics) performance and portable emissions measurement system (PEMS) response towards measurements, etc. Some of these conditions are reviewed here.

Effect of Temperature

For gasoline vehicles, cold-start emissions increase at high load and under suburban and highway driving. For diesel vehicles, such cold start emissions slightly decrease (Weilenmann et al., 2005). Generally, as the ambient temperature goes down, the emissions increase, particularly for PN, and the NOx emissions increase at high temperatures. During RDE, when vehicles were tested at cold ambient temperature (-7°C), there were 2.3 – 6 times higher emissions (except NOx for diesel vehicles) than EURO-6 standards. Emissions disproportionally increased with relatively high particle number (PN) emissions ($>1 \times 10^{11}$ # km^{-1}) from gasoline vehicles (Suarez-Bertoa & Astorga, 2018). It signifies that emissions are dependent on ambient temperatures. Therefore, the local conditions should be considered while setting the ambient temperature limits for conducting the RDE test.

Effect of Humidity

As the humidity increase, the availability of oxygen decreases so does the incomplete combustion. CO, HC, and PN emissions increase and NOx decrease (Li et al., 2013). (Morawska et al., 2008) showed that nucleation mode particles were primarily influenced by relative humidity with high concentrations during high humidity periods. Since short-term variation in humidity is large and cannot be regulated, humidity is generally not part of the RDE test.

Effect of Altitude

As the altitude increases, the air and fuel ratio reduce and cause incomplete combustion inside the engine. High altitude reduces NOx emissions but increases HC, CO and PM manifolds, and torque reduces, causing fuel consumption to increase. At low speeds conditions, idle and/or cold start conditions, the emissions at high altitude increase manifold except for NOx (Chaffin & Ullman, 1994; Ghazikhani et al., 2013; He et al., 2011; Human et al., 1990; Kan et al., 2017; McCormick et al., 1997; Wang et al., 2013). It is important to duly account for the range of altitude while fixing the conditions for RDE procedures.

Effect of Wind flow

The wind flow causes a drag on the vehicle and can change the emissions on the road. Since short-term variation in wind flow is large and cannot be regulated, during RDE test, winds should be calm as far as possible (ECE /TRANS/WP.29/GRPE/2020/14) during RDE test.

Effect of Driving Style

The emissions are influenced by driving behavior and the greater understanding of the behavioral factors will aid in the development of more appropriate and effective procedures for RDE tests (Arumugam & Bhargavi, 2019; Fraidl et al., 2016). The driving behavior also depends on behavioral, environmental, physiological, psychological and emotional factors (stress, fear, heart rate and anxiety).

The driving habits vary widely and it cannot be part of RDE conditions. However, well-trained persons should conduct driving during the RDE test and maintain uniformity in the driving style during the RDE test.

Effect of speed/velocity

Vehicle speed is a critical factor that affects instantaneous engine power. Instantaneous engine power is more sensitive to speed than acceleration (Yao et al., 2014). RDEs for LDVs are high at low speeds

(< 40 km/hr) and high speeds (over 95 km/hr) (Donateo & Giovinazzi, 2017; Yao et al., 2014), vehicles fuel efficiency is optimized in specific speed range. The variability in vehicle speed must be considered in RDE tests.

Effect of Acceleration

For lower speeds, the acceleration rates usually vary much more than at high speeds. The emission vs speed multiplied by acceleration becomes a good measure to get insight into vehicle emission characteristics (Joumard et al., 1995). It was found that statistically, emissions are different at different acceleration levels and there is no relation between deceleration rate and tailpipe emission (Shridhar Bokare & Kumar Maurya, 2013). As the acceleration increase, the emissions increase (Ahn et al., 2002; Rakha et al., 2000). Since variability in acceleration is an important factor thus, acceleration is an essential part of the RDE test. This issue of acceleration is covered under bounds for relative positive acceleration (RPA) and V·apos (product of vehicle speed and positive acceleration) (discussed later).

Effect of Drive cycle (urban, rural and highway)

Large fractions of the PM are emitted at the engine start and during the first 200 seconds. Aggressive drive (for urban and highway) patterns emit multi-time more emissions than normal driving (rural). Aggressive drive patterns also emit more elemental carbon and PN/PM. After the vehicle is fully warmed up, the PM emission, even during aggressive drive pattern with the hot-start is reduced (Giechaskiel et al., 2019; Suarez-Bertoa et al., 2019; Wei et al., 2009). An appropriate drive cycle should be designed which represents typical driving on urban, rural and highway.

Effect of Inertia weight

An increase in inertia weight by 50% to 100% of the vehicle leads to more than 100% increase in PM emissions and a slight increase in NOx emissions (Clark et al., 1994; McCormick et al., 1998; Yanowitz et al., 1999). It is reported that LDVs contribute to roadside PM in 30-60 nm range and HDVs (mainly diesel vehicles) contribute in accumulation mode (0.3–1 μm) (Charron & Harrison, 2003). Different Inertial weights is considered in RDE test in the classes of inertial weight.

PEMS

To measure pollutant emissions during real driving, cars are fitted with PEMS that provide complete real-time monitoring of the key pollutants emitted by the vehicle. The PEMS used for regulatory emissions is complex equipment that integrates advanced gas analyzers, exhaust mass flow meters, weather station, and Global Positioning System (GPS).

Conformity Factors: To account for measurement uncertainty of the onboard equipment compared to laboratory ones, conformity factors apply to the on-road emissions. Conformity factor is defined as a 'not to exceed limit' that considers a margin for error, which is present simply because the PEMS equipment does not deliver precisely the same results for each test. The results of the RDE emissions for the entire RDE trip should remain below the Not to Exceed (NTE) emissions limits as defined by the following equation:

$$NTE_{pollutant} = CF_{pollutant} \ x \ EmissionLimit$$

For example, the concept of CF prescribed in EU is shown below in Figure 11

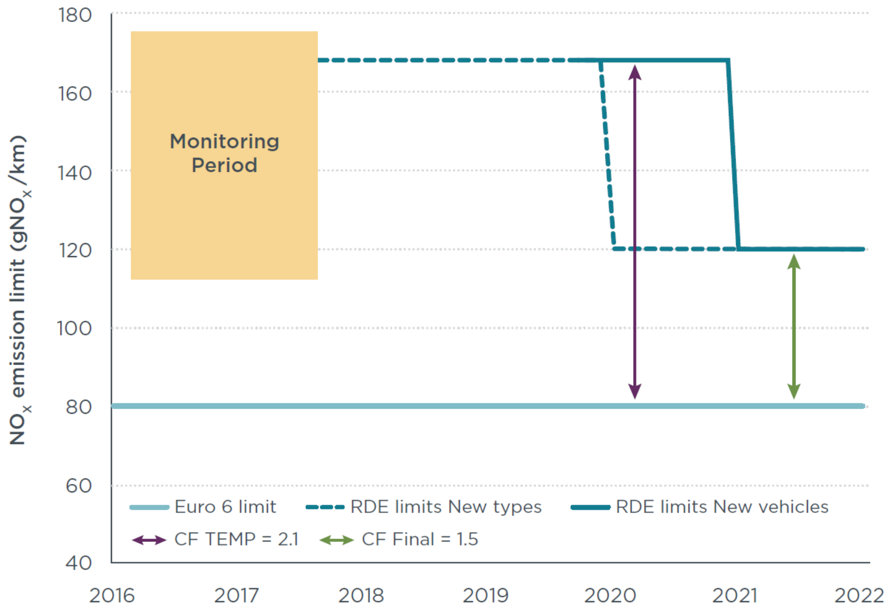

Figure 11: Time line of CF for NOx emissions (Mock, 2017)

On-board diagnostics (OBD)

OBDs are used to regulate the vehicle's optimum performance for emissions, customer comfort and highest safety. Most OBDs are computing devices that control equipment. OBD data are used for post calculation after the RDE test is conducted.

European RDE

The implementation of the European RDE test has been progressively described in four packages (March 2016 and November 2018 for EURO-6 vehicles (2016/427, 2016/646)).

The 1st package included the basic features of the RDE test, including the trip characteristics, description of data evaluation tools, technical requirements of the PEMS equipment, and reporting obligations. The focus was on gaseous emissions, primarily NOx. The 1st package was only for monitoring and reporting with no requirement to meet not to exceed (NTE) limit. It applied to NEDC approved EURO-6c vehicles.

The 2nd package included NTE limits on NOx equivalent to the EURO-6 limit multiplied by a conformity factor (described above) and a timetable for RDE implementation. It also included several technical features such as dynamic boundary limits [8](RPA (relative positive acceleration) and V·apos (product of vehicle speed and positive acceleration), a limit on the altitude gain and GPS validation. Vehicles were required to conform to a NOx CF of 2.1 from September 1, 2017 (EURO-6d-TEMP: (Demuynck et al., 2016) and 1.5 starting January 1, 2020 (EURO-6d). Cold start emissions were excluded.

The 3rd package included the introduction of a PN measurement protocol and associated conformity factor, procedures for having cold starts and regeneration events in the RDE test, and provisions for hybrid vehicles. A PN CF of 1.5 was applicable from September 2018. The introduction of the 3rd package coincided with the introduction of WLTP.

The 4th package formed the basis of in-service conformity (ISC), surveillance tests, and specific provisions for light commercial vehicles. The conformity factor for NOx was lowered to 1.43. The data evaluation method was simplified to so that the measured distance-specific result is equal to the test result unless the distance-specific CO_2 emissions during RDE testing are more than 20%-30% higher than during WLTP testing.

The conditions for prescribing the range of ambient air temperature and altitude and other requirements for RDE test by EU, China are given in Table 2. The CF for different countries is given in Table 3.

[8] To assess trip dynamics two requirements have been introduced in the RDE legislation: the 95th percentile (P95) of v*apos and the average RPA. The parameter v*apos, the product of vehicle speed and positive acceleration, is commonly used as an indicator for high(er) dynamics of a trip and RPA, the relative positive acceleration, as an indicator for the lack of dynamics in a trip

Table 2: Comparison Between EURO-6 and China 6 RDE Requirements (*China's Stage 6 Emission Standard for New Light-Duty Vehicles (Final Rule)*, 2017)

Requirement		EURO-6	China 6
Application	Type Approval/Test	Yes	Yes
	In-service test	Yes	Yes (2023)
Emission standard	Limits M1 and M2 Vehicles (see Appendix A.1)	NOx: Diesel: 0.08 g/km Gasoline: 0.06 g/km PN: 6 x 10^{11} #/km	Fuel-neutral NOx: 0.035 g/km PN: 6 x 10^{11} #/km
	Conformity factors for NOx and PN (effective date)	All new vehicles: 1.5 (1/1/2021)	All new vehicles: 2.1 (7/1/2023)
	Cold starts	Included	Excluded
Trip requirement	Total trip duration	90–120 min	
	Minimum distance for each segment	Urban: 16 km Rural: 16 km Motorway: 16 km	
	Trip composition	Urban: 29%–44% of total distance Rural: 23%–43% of total distance Motorway: 23%–43% of total distance	
	Average speed	Urban: 15–40 km/h Rural: 60–90 km/h Motorway: >90 km/h	
	Stop percentage during urban segment	6%–30%	
	Maximum speed during motorway segment	145 km/h (160 km/h for 3% of motorway driving time)	120 km/h (135 km/h for 3% of motorway driving time)
	High-speed duration during motorway segment	At least 5 min driving at >100km/h speed;	
Boundary condition	Payload	≤90% of maximum weight	
	Ambient temperature	Moderate: 0°C–30°C Extended: -7°C–0°C, 30°C–35°C	Moderate: 0°C–30°C Extended: -7°C–0°C, 30°C–35°C
	Altitude	Moderate: <700 m Extended: 700 m–1,300 m	Moderate: <700 m Extended: 700 m–1,300 m Further extended: 1,300 m – 2,400 m
	Correction factor	Extended: 1.6	Extended: 1.6 Further extended: 1.8
	Altitude requirements	Start and end point shall not differ more than 100 m in altitude Maximum cumulative altitude increase: 1,200 m over a distance of 100 km	
	Dynamic requirements*	For each segment, Max. limit is defined as the 95th percentile of v*a (speed * positive acceleration) Min. limit is defined by the RPA (relative positive acceleration)	
	Use of auxiliary systems	Free to use as in real life	
Evaluation methods	Data evaluation methods	Moving average window method or power binning method	Moving average window method
	Verification of test normality in moving average window method	Maximum primary tolerance for the CO_2 characteristic curve: 30%	Maximum primary tolerance for the CO_2 characteristic curve: 50%

*(see Figure 12)

Table 3: Emission CFs for different emission norms

Country/Standard	NOx CF	PN CF	CO
EURO-6d	1.43	1.5	Monitoring
China 6b	2.1	2.1	Monitoring
Japan PPNLT	2 (Diesel)	-	-
South Korea K-LEV-III (Gasoline), EURO-6 (Diesel)	1.5 (Diesel)	-	-
Bharat Stage VI	Monitoring	Monitoring	-

(Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 Setting CO2 Emission Performance Standards for New Passenger Cars and for New Light Commercial Vehicles, and Repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (Text with EEA Relevance.), 2019)

Passenger Car emission limits for different countries is given in Appendix A.2

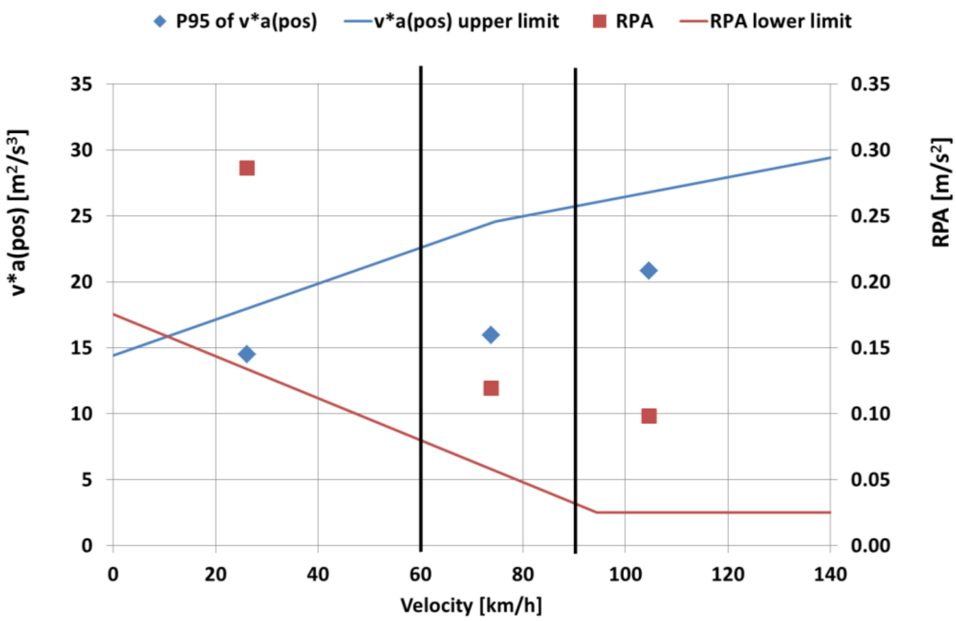

Figure 12: Driving dynamics parameters P95 of v*apos and average RPA from one of the RDE trip performed at TNO compared to the RDE limits for P95 of v*apos and average RPA (Heijne et al., 2016)

2.1.1 Indian RDE Regulation

During type approval and COP applicable from 1st April, 2020, real world driving cycle emission measurement using PEMS shall be carried out for data collection and from 1st April, 2023, the real world driving cycle emission conformity shall be applicable. The detailed procedure is laid down in AIS-137 (Part-3) and as amended from time to time. The draft procedure is summarized in Table 4.

Table 4: Indian RDE Regulation – Draft (Govt. Notification, GSR 889(E), 16th Sep 16)

Points	M Category	N1 Category	M1 & N1 (Low Powered) (PMR < 22kw/ Ton & Max. Designed Speed ≤ 70 kmph)
Environment Boundary Conditions			
Temperature	Moderate: 10°C ≤ T ≤ 40°C, Extended:40°C < T ≤ 45°C ; 8°C ≤ T < 10°C		
Altitude	Moderate: A ≤ 700 m , Extended: 700 < A ≤ 1300 m		
Trip Requirements			
Speed Ranges	Phase1: V < 45 km/h Phase2: 45 ≤ V <65 km/h Phase3: V ≥65 km/h; V>75km/h for min 5 min	Phase1: V < 40 km/h Phase2:40 ≤V <60km/h Phase3: V ≥ 60 km/h V>70km/h for min 5 min	Phase1: V < 45 km/h Phase2: V ≥ 45 km/h V>55km/h for min 5 min
Trip distance share	Phase 1: 34 % (±10%) Phase 2: 33 % (±10%) Phase 3: 33 % (±10%)		Phase 1: 50 % (±10%) Phase 2: 50 % (±10%)
Maximum vehicle velocity	For M1: Wherever legal max speed limit permits, the vehicle velocity can exceed 100 km/h for not more than 3 % of the time duration of the Phase 3 driving, maximum up to 120km/hr. For N1: Restricted to 80km/h. For LP M1/N1: Restricted to 70 km/h		
Phase 1 Average Speed	15-30 km/h		
Total trip duration	90 – 120 min		
Minimum Distance	16km for each Phase (Phase 1, Phase 2, Phase3) (Same for M1/N1)		24 km for each phase (Phase 1, Phase 2)
Stop periods	• 6 to 30% of Phase -1 duration • May contain several stop periods of 10 seconds or longer. • Single stop period must not exceed 5 Mins. • Vehicle should not be driven continuously below 20 km/h for more than 20 minutes.		
Trip Dynamics			
Number of Acceleration points	Minimum 150 for each for Phase1, Phase2 Minimum 100 for Phase3		Minimum 150 for Phase 1 Minimum 100 for Phase 2
Relative Positive Acceleration (RPA)	(V≤55.9 km/h) Y = -0.001825 X + 0.1755 (V>55.9 km/h) Y = -0.0011 X + 0.1350	Y = -0.0016x + 0.1406	(V≤ 54.76 km/h) Y = -0.0022X + 0.1271 (V> 54.76 km/h) Y = 0.0066
V*Apos	(V≤56.9 km/h) Y = 0.0467X + 12.2490 (V>56.9 km/h) Y= 0.1665 X+ 5.4352	(V ≤ 51.40 km/h) Y= -0.0614X + 6.9439 (V> 51.40 km/h) Y= 0.0045X + 9.8664	Y = 0.0142X + 4.6214
Post Processing			
Reference Cycle	MIDC (Cold Start) as per Emission Type Approval Procedure		
CO_2 Multiplication Factor	1.1,1.1	1.05,1.05	1.05,1.05
Moving Avg. Window Speed Bins	35,55	35,55	35
CO_2 Weightage for MAW Window	100 % CO_2 (Grams) of MIDC Cycle		
Normality /Completeness	Normality – 50%; Completeness – 10%		
The completeness and normality of the real road test results according to the MAW (moving average window) method. The MAW method uses the average velocity in each window to identify urban, rural, or motorway roads.The **completeness** requirement is that, driving distance of each phase should be 15% or more. The **normality** criterion states that at least 50% of the data should be in the normal condition in each window; (Song & Cha, 2021).			

3 Robust Indian RDE program

ICAT performed chassis dynamometer and RDE tests for Indian vehicles (three light-duty diesel and petrol vehicles,) as a part of a study sponsored by the International Council on Clean Transportation (ICCT) (Bandivadekar & Posada, 2017). The data showed the gap between laboratory and RDE, suggesting the needs for vehicle technologies and regulations to improve emissions on the road through a well-designed RDE test procedure.

The vehicle testifying agencies in the European Commission and the USA insist on the performance of vehicles under real driving conditions. RDE on-road tests are becoming mandatory worldwide. Specialized equipment installed on the vehicle collects data to verify that the legislative caps for pollutants such as NOx are adhered to while on the road. In India, an adequate RDE test cycle may undo the benefits of BS-VI. The challenge in RDE tests is the trip (speeds, distances, durations, etc.) selection that can offer an RDE driving cycle. The EU has formalized the RDE driving cycle concerning overall traffic, road, and physical ambient conditions. The Indian agency, International Centre for Automotive Technology, is currently developing RDE procedures that are likely to come into force in 2023. The RDE cycle must cleverly account for conditions prevailing in the country, such as low and high altitudes, year-round temperatures, additional vehicle payload, up and downhill driving, urban and rural roads, and highways.

The present report has summarized the driving cycles and RDE test procedures used internationally. Since India is in the process of finalizing the RDE test procedure and has a draft procedure in place, the following points come to the fore to make the Indian RDE program robust and in accordance with Indian conditions.

1. India has a sizeable hilly area spread out in various parts of the country. The motorable altitude is in the range MSL to 3500 m. Most vehicles' common range for altitude is expected to be MSL to 1300 m, excluding driving in Himachal Pradesh, Laddakh, Uttarakhand and Jammu-Kashmir and northeast. The India RDE should extend altitude limits up to 2400m MSL. Second option is to implement a policy to sell and drive carbon zero fuels and renewable electricity vehicles in high altitude areas in excess of 1300 m. Around 11% of India’s population live in hilly areas above 500 MSL (according to year 2011 census). These areas also have low temperature (< 7°C for log timespan). Therefore, these areas must implement low emission vehicle sell only.

2. India has a large area with a significant time span of near and sub-zero temperature zones in winter months. The lower temperature limits should extend to 0°C. Almost entire north-west (around 36% of India's population) of India experience near sub-zero temperature during winter (Nandi, 2020).
3. India is still using MIDC for type approval which is far from international laboratory testing cycles. India must use WLTP and appropriate WLTC for TA and COP.
4. India has a capping speed of 90 km/hr for emissions certification. On the highways, vehicles usually have a speed of more than 90 km/hr. Therefore, the application of full WLTC as used by EU should be considered.
5. During urban rush hours, vehicle populations are very high, resulting in low speeds and high acceleration and deceleration conditions; these should be considered in the choice of WLTC version.
6. The specifications of PEMS (range of measurement, technology, calibration, durability requirements etc.) should be published so that OEMs can use the right PEMS for further technology development.
7. Indian market has highly efficient multi-point fuel injection (MPFI) diesel vehicles and such vehicle can achieve lower PN/PM emissions with tail pipe emission control devices. Therefore, the PM/PN limits can be further tightened in heavy-duty diesel vehicles.
8. India needs to define CFs for RDE testing, comparable to international counterparts and Indian requirements. EU has implemented CFs at 1.5 (NOx and PN) level for EURO-6b. In due course of time, the emission limits during RDE should become fuel neutral.
9. Emission control can be achieved via after combustion emission control technologies, like catalytic converters[9] (diesel oxidation catalyst, selective catalytic reduction, lean NOx catalyst, lean NOx trap, non-selective catalytic reduction system), exhaust gas recirculation (EGR), particulate filters (partial or flow-through filters, high-efficiency wall-flow filter (DPF, GPF)), engine/fuel management (EGR, variable valve timing), enhanced combustion technologies (gasoline direct injection, variable geometry turbocharging), use of best OBD to get best performance of engines/vehicle, and proper use of evaporation control technologies. Appropriate technologies must be developed on priority by Indian OEMs.
10. Road maintenance and marking, smart traffic signaling, the standard design of the speed breakers, speed warnings and traffic discipline are important contributors to RDE. These factors should be optimized in urban, rural roads and highways.

[9] Reference - http://www.meca.org/technology/technology-details?id=5&name=Catalytic%20Converters

11. Poor quality lubricants and their inappropriate recycling is an important cause of RDE. The quality of lubricant should improve and recycled unorganized sale of the lubricants should be stopped.

4 Scrapping policy in India

The vehicle owners in India tend to continue to use their vehicles well beyond the expected life of the vehicle. Such vehicles emit higher emissions; have lower fuel efficiency and lesser safety features. Therefore, there is a need for an incentive-based scheme to encourage vehicle owners to replace their older vehicles with new generation products which are more efficient, safe and environmentally benign. To this effect, Central Government launched the Vehicle Scrappage Policy on August 13, 2021 (*Section 59(4) of the Motor Vehicles Act, 1988 (59 of 1988)*, 2021). The policy will kick in for government vehicles from April 1, 2022. Mandatory fitness testing for heavy commercial vehicles will start from April 1, 2023, and for all other categories of vehicles, including personal vehicles, it will start in phases from June 1, 2024.

The purpose of the Vehicle Scrappage Policy is to phase out old and inefficient vehicles and recycle them through a well-structured system This policy will reduce air pollution caused by old vehicles that have surpassed their lifecycle and not roadworthy. It is expected that the scrapping of old vehicles would result in more benefits than just reducing air pollution. Recycling old vehicles will help reuse critical materials like steel, plastic and copper, thus reducing the cost of manufacturing. The policy will also help boost to clean BS-VI vehicle sales in the country.

Fitness tests are required to know the quality of the vehicle, if it is still fit to run on the roads and how much effect it will have on the environment. A vehicle will be declared fit or unfit after conducting multiple tests like brake test, engine performance and others. If a vehicle passes the fitness test, it will have to repeat the same after every five years to keep a check. A valid fitness certificate will be necessary for the renewal of registration certificates after 15 years. The renewed certificate will be issued for 5 years in the case of private vehicles.

Which vehicles will be scrapped?

Under the new policy, vehicles will not be scrapped merely based on age. As mentioned earlier, they will be scientifically tested through authorized, automated testing centres. Unfit vehicles will be scrapped scientifically to ensure that registered vehicle scrapping facilities all over the country are technology-driven and transparent. The term 'unfit' vehicles include those who fail to qualify a fitness test; have been damaged due to fire, riot, natural disaster, accident or any other calamity; declared obsolete or beyond repair; vehicles that have outlived their utility. Vehicle Scrappage Policy 2021 will include all types of vehicles like Passenger, Commercial and Taxi purpose vehicles also.

India has 17 lakh (1 lakh = 100000) medium and heavy commercial vehicles that are older than 15 years without any valid fitness certificate, 51 lakh light motor vehicles older than 20 years and 34 lakh light motor vehicles older than 15 years, ("Vehicles Scrappage Policy Launched," 2021) according to the Transport Ministry. The average age of commercial vehicles is over 10 years and the private ones, 10-15 years.

Environmental benefit

In this Vehicle Scrappage Policy 2021 all the unfit vehicles in India will be converted to scrap in a very scientific way. Owners of Vehicle will be given incentives in the form of cash incentives which will be 5-6% Value of Showroom Price and the vehicle registration fee will be waived off.

Incentive Program

Incentive Program under Vehicle Scrappage Policy 2021 will be that the owner will be given cash incentive. This incentive will differ as per the Showroom price of car, it varies from 4-5% of Showroom price of car. If we talk about Maruti Suzuki Swift, then this Vehicle's incentive will be upto Rs. 1,00,000 including rebate of RTO fees. This is the finest initiative by the Government of India to discard unfit vehicles from Indian roads.

This will encourage people to discard their old cars and opt for new cars with incentives which the Government will give in lieu of discard vehicles. Commercial vehicles will also be under the radar of this Vehicle Scrappage Policy 2021 and they also have to undergo the fitness test which the Government will conduct. The benefits of Vehicle Scrappage Policy 2021 include;

- 4-5% Showroom price will be given as cash return;
- Tax rebate will also be given up to 25% for new vehicle registration; and
- Showrooms and dealers will also give discounts on showing scrappage certificates of Old Vehicles.

What has the world done so far on vehicle scrappage? (Raghunath & Kapoor, 2019)

Salient point	EU	Japan	Korea	China	US
ELV management system	Directive 2000/53/EC Of The European Parliament And Of The Council of 18 September 2000 on end-of life vehicles (enforced in 2000)	Law for the Recycling of End-of-Life Vehicles (enforced in 2005)	Act for Resource Recycling of Electrical/ Electronic Equipment and Vehicles (enforced in 2008)	End-of-Life Vehicle Recycling Regulation (enforced in 2001) Automotive Products Recycling Technology Policy (declared in February 2006)	Resource Conservation Recovery Act Clean Air Act, etc.
Target automobile	M1, N1	All vehicles (including buses, trucks, etc.), with the exception of two- wheeled Vehicles	M1, N1	M1, M2, M3, N1, N2, N3	All vehicle categories
Recycle target	Until 2006: Recovery: 85 % Recycle: 80 % Until 2015: Recovery: 95 % Recycle: 85 %	Airbag: 85 % ASR: 70 % (from 2015 onwards) 50 % (2010 to 2014) 30 % (2005–2009)	Until 2014: Material + Energy recovery: 85 % (of which energy recovery rate is within 5 %) After 2015: Material + energy recovery: 95 % (of which energy recovery rate is within 10 %)	Possibility of recycling: 2010: about 85 % (material recycling of 80 % or more) 2012: about 90 % (material recycling of 80 % or more) 2017: about 95 % (material recycling of 85 % or more	No specific goals (95 % of ELVs enter the recycling route, of which 80 % of the materials are recycled)

5 Summary and recommendations

The MIDC adopted in the year 2000 is a significant improvement over IDC. MIDC is nearly equivalent to NEDC and accounts for wider speed profiles idling conditions observed in real-world driving. The maximum speed in the MIDC cycle is set to 90 km/h.

The acceleration profiles in the Indian urban areas vary significantly from the prescribed acceleration in MIDC. The realistic speed-acceleration profiles are considerably higher than that mandated in MIDC. In high power requirement zones, the accelerations and decelerations are not well reflected in the MIDC and under such conditions vehicles may emit high NOx and other pollutants.

Many countries have adopted the Worldwide Harmonized Light Vehicle Test Cycle (WLTC). The WLTC is a global harmonized standard for determining the levels of pollutants. The WLTP has (i) a wider range of driving conditions; (ii) simulates a longer distance; (iii) higher average and maximum drive power; and (iv)Steeper accelerations and decelerations. The WLTP is widely used procedure and to overcome the limitations of MIDC, India should move to WLTC.

The RDE test measures the pollutants emitted by vehicles while driven on the road, such as NOx. RDE ensures that cars deliver low emissions over on-road conditions. India is conducting RDE test as per the draft framework and collecting the data for finalizing the RDE test procedure that will come into force from April 2023. In RDE test the emissions are dependent on ambient temperatures, altitude, vehicle dynamics, speed range, specification of PEMS and RDE test should duly account these variables.

India has a sizeable hilly area spread out in various parts of the country. The motorable altitude is in the range MSL to 3500 m. The India RDE should extend altitude limits up to 2400m MSL. India has a large area with a significant time span of near and sub-zero temperature zones. The lower temperature limits should extend to 0°C.

The specifications of PEMS (range of measurement, technology, calibration, durability requirements etc.) should be published so that OEMs could use the right PEMS for further technology development. Indian market has highly efficient multi-point fuel injection (MPFI) diesel vehicles and such vehicle can achieve lower PN/PM emissions, a stringent PM/PN limits can be considered for such heavy-duty diesel vehicles.

India needs to define CFs for RDE testing, comparable to international counterparts and Indian requirements. EU has implemented CFs at 1.5 (NOx and PN) level for EURO-6d. In due course of time, the emission limits during RDE should become fuel neutral.

Road maintenance and marking, smart traffic signaling, the standard design of the speed breakers, speed warnings and traffic discipline are important contributors to RDE. These factors should be optimized in urban, rural roads and highways.

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7 Appendix A.1

UNECE Vehicle categories (from Consolidated Resolution on the Construction of Vehicles (R.E.3) Revision 6)

M	Vehicles having at least four wheels and used for the carriage of passengers (e.g., standard car with 2, 3, 4 doors).
M1	Vehicles used for carriage of passengers, comprising not more than eight seats in addition to the driver's = 9.(Larger Than Standard Car e.g.: London Cab / E7 Type Vehicle 8 seat + Driver.)
M2	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes. (Bus)
M3	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes. (Bus)
N	Power-driven vehicles having at least four wheels and used for the carriage of goods
N1	Vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes. (Pick-up Truck, Van)
N2	Vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes. (Commercial Truck)
N3	Vehicles used for the carriage of goods and having a maximum mass exceeding 12 tonnes. (Commercial Truck)

8 Appendix A.2

Pollutant emission limits for different Countries

Passenger Car (gm/km)										
		HC	**HC+NOx**	**NOx**	**PM**	**N2O**	**HCHO**	**NMHC**	**CO**	**PN**
Gasoline	EURO-6	0.1		0.06	0.005				1	6E+11
	LEV III		0.099		0.0062		0.0025		2.610	
	Japan			0.05	0.005			0.1	1.15	
	China 6a	0.1		0.06	0.0045	0.02		0.068	0.7	6.00E+11
	China 6b	0.05		0.035	0.003	0.02		0.035	0.5	6.00E+11
	India BS6	0.1		0.06	0.0045			0.068	1	6.00E+11
Diesel	EURO-6		0.17	0.08	0.005				0.5	6E+11
	LEV III									
	Japan	0.024		0.15	0.005				0.63	
	China 6a	0.1		0.06	0.0045	0.02		0.068	0.7	6.00E+11
	China 6b	0.05		0.035	0.003	0.02		0.035	0.5	6.00E+11
	India BS6		0.17	0.08	0.0045				0.5	6.00E+11