Assessment of emission test driving cycles in India: A case for improving compliance

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Abstract

Driving cycles are extremely important in establishing compliance of emission control norms for vehicles. Internationally, it has been observed that there are considerable differences between the driving conditions of type-approval cycles and those of real-world vehicle use. This leads to real-world emissions being higher than expected, and hence, failure of employed policies. The current study assesses the real-world driving conditions in different Indian cities and compares them with the Indian driving cycles followed for different categories of vehicles. The driving cycle for different categories of vehicles (cars, two-wheelers, and buses) are distinctly different and not representative of the actual driving conditions in India. A case for world-harmonized driving cycles is also assessed for India and the proposed cycles are compared with the existing ones. World harmonized cycles cover a wide range of speed and acceleration profiles, and hence, they provide fewer opportunities to meet the standards only on the cycle while emitting much more in the real world. Moreover, the standardization of these procedures at the global level allows manufacturers to design vehicles for various markets and not just for an individual country.

1. Introduction

Driving cycles are the means to represent on-road driving conditions for a particular country or region. They are developed to take into account the varying on-road driving conditions (idling, cruising, accelerating, and decelerating) and serve as an important input for testing of tail-pipe emissions and fuel efficiencies of different categories of the vehicles. They have also been instrumental in assessing transport management strategies (Bata et al., 1994; André, 1996). A driving cycle is formulated through statistical analysis of vehicle trip databases made by carrying out extensive road driving experiments under varying conditions (such as different road, and traffic densities) to eventually represent a working day driving pattern in a region. Driving cycles can be used to represent the average driving pattern in a region, or specific driving conditions to be investigated at the chassis dynamometer (*e.g.* cold starts).

The Indian Driving Cycle (IDC) was the first driving cycle in India. This cycle, which was introduced in 1985, was based upon extensive road tests conducted by Automotive Research Association of India (ARAI), Pune. Since then some changes have been made to the cycle. However, the growing number of vehicles and limited growth of road infrastructure has led to increased congestion levels in urban centres of the country. (WSA) 2008 came out with congestion indices of different cities highlighted the fact that cities like Delhi, Mumbai, Varanasi, and Bangalore are dealing with the highest congestion levels. A study by the Central Road Research Institute (CRRI) reported an annual loss of fuel worth Rs 994 crores due to idling in Delhi. Congestion not only leads to reduced speeds of the vehicles but also distorts the driving cycles prescribed for emission test procedures. On the other hand, infrastructural developments in roads and highways have led to increase in speed and acceleration profiles in non-congested driving patterns. A shift towards high-powered cars also indicates shifting speeds and acceleration profiles. In all, the Indian driving profiles have changed significantly since 1985 due to the growing number of vehicles and road infrastructure.

Weiss et al, 2012 explains how the European type-approval procedures have not assured the compliance of the on-road NOx (oxides of nitrogen) emissions from diesel cars, due to similar discrepancies between the test cycles and real-world operation. Shukla, 2010 also shows the high pollutant emissions in actual on-road conditions in Delhi.

All this suggests that driving cycles prescribed for emissions testing are not representative of real-world driving conditions. Although the vehicles tested on the driving cycles (for type approvals) comply with emission regulations, they may emit much more under real-world conditions. Hence, even though it is impossible to fully recreate all real-world conditions, test cycles should include diverse driving modes and should prompt the manufacturers to limit the emissions within the prescribed standards in most driving conditions.

The current paper analyses the Indian driving cycle vis-a-vis driving cycles in other countries. A literature review exercise has been carried out to understand its limitations and possible improvements. Real-world driving conditions were mapped in four cities of India falling in different geographical zones, representing different cultures, population densities, climate, and road conditions. The results of the actual primary surveys are compared with the IDC to assess the deviations. A case for introduction of the world harmonized driving cycles in India is also evaluated.

2. Indian driving cycles

In view of enforcing emission control on vehicles in India, the first Indian Driving Cycle (IDC) was first developed by Automotive Research Association of India (ARAI) in 1985 under the Central Motor Vehicles Rules in India. The cycle was based on actual on-road measurements conducted by ARAI, Pune. IDC is still followed in India for testing of emissions from two/three wheelers, which are 73 per cent of the total registered vehicle population in India. IDC is actually a very short cycle (although comprising six driving cycles modes) of just 108 seconds and does not cover all the different driving conditions observed on the road. The average speed of IDC is 21.9 km/h (covering 3.94 km), which also seems to be high in view of rising congestion levels in Indian cities. Moreover, all two- and three-wheeler vehicles except diesel vehicles are run with 40 seconds idling as preconditioning before sampling on chassis dynamometer (MoRTH, 2000), which does not properly account for cold start emissions.

Recently in 2012, Government of India introduced WMTC (world motor-cycle test cycle) as an alternative regulation for BS III two-wheelers in India. It is expected that the WMTC will become mandatory when BS IV regulations for two-wheelers come into effect after 2015.

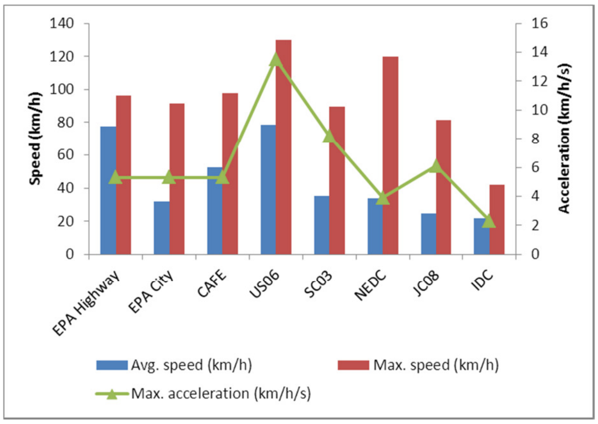
While IDC is still used for testing of two- and three-wheelers in India, MIDC (modified Indian driving cycle) is used for assessing emissions from cars and LCVs. MIDC was adopted in the year 2000 and was later modified with a better cold start testing procedure. It is mostly the same as Europe's NEDC (New European Driving Cycle), which is made up of four ECE-15 Urban Driving Cycles (UDC[1]) and an Extra-Urban driving cycle (EUDC[2]). However, the maximum speed in the MIDC cycle has been reduced to 90 km/h considering Indian conditions (Figure 1b). The test procedures for NEDC were standardized by UNECE

[1] UDC represents city driving conditions with low vehicle speeds, low engine load, and low exhaust gas temperature.

[2] EUDC accounts for more aggressive, high-speed driving modes up to 120 km/h in NEDC and 90 km/h in MIDC

World Forum for Harmonization of Vehicle Regulations. It is to be noted that both IDC and MIDC includes cold start procedural testing.

A comparison of Indian driving cycles (IDC and MIDC) with others in the world is presented in Figure 1a, which shows that Indian cycles assume lower speeds in comparison to cycles followed in other countries. Figure 1b shows the extensive speed profiles covered by MIDC in comparison to the IDC.



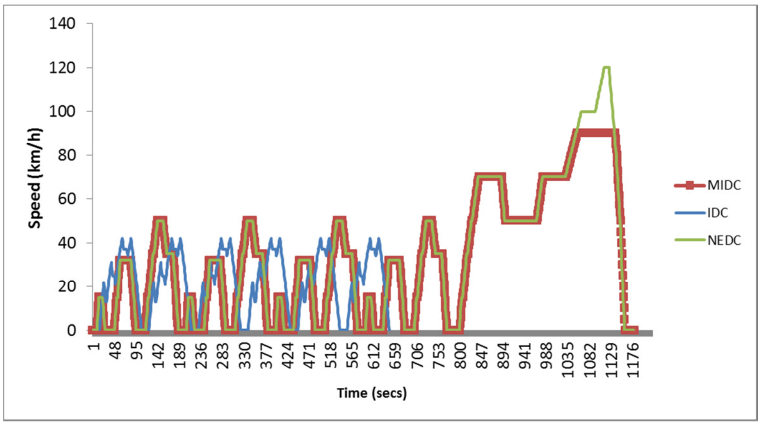


Figure 1a Comparison of average and maximum speeds and maximum accelerations under different driving cycles followed across the world

Figure 1b Indian Driving Cycle and Modified Indian Driving Cycle (IDC and MIDC)

The suitability of IDC as the standard cycle for testing in India has been questioned by many research studies. Kamble, 2009 stated IDC as unsuitable for evaluating fuel consumption due to its gentle acceleration, braking, and long periods spent in stationary mode.

Chugh et. al., 2012 contested that MIDC may not give a realistic assessment of vehicular emissions in actual on-road conditions. They attributed the variations to differences in traffic density, land-use patterns, road infrastructure, and traffic management.

Kumar et. al., 2011 commented on the homogeneity of the traffic assumed in the IDC, hence ignoring the actual heterogeneous composition of traffic on Indian roads. Nesamani, 2005 also concluded that IDC does not represent the real-world driving and also confirmed that it may lead to underestimation of the emission rates. Table 1 presents the differences observed by different Indian studies of real-world driving compared to the IDC.

Table 1 Specification observed in different driving cycles

Cycle	Time (sec)	Avg. speed (km/h)	Max. speed (km/h)	Max. acceleration (m/s²)
IDC	108	21.9	42	0.64
Pune (Kamble, 2009)	1533	19.6	55	27% times >1
Bangalore, Chennai, Mumbai, Kolkata (Sriniwas et al, 2011)	3444	20	70.8	0.8

Based on these, the major limitations of the IDC can be summarized as follows:

1) IDC does not take into account the higher speeds (>42 km/h) and accelerations (> 0.65 m/s^2), which means the vehicles running at high speeds/highly transient conditions can have higher in-use emissions, while they could still pass the emission tests on the prescribed driving cycles.

2) IDC assumes all traffic to be homogenous, and it does not take into account the varying conditions in which real-world traffic operates. In reality, traffic movement is highly dependent on street design, quality of roads, traffic lights, congestion levels, and driver behaviour.

3) IDC assumes low accelerations as observed in real-world driving conditions (on broader roads, hilly terrains, and highways). Considering undulating terrains found in many parts of the country, the cycle should account for higher engine loads which may lead to higher emissions.

For heavy and commercial vehicles, the earlier used ECE R49 test has now been replaced by ESC and ETC cycles followed in Europe. ECE R49 cycle was a steady-state diesel engine test cycle used for type approval emission testing of Euro II equivalent vehicles (Delphi, 2012). ESC[3] and ETC tests were proposed in the Auto Fuel Policy (MoPNG, 2002) for testing of Euro III/Euro IV equivalent vehicles. Rexeis et. al., 2005 showed that ECE R49 test was not able to ensure reduction in emission (especially for NOx) for all real-world driving conditions, and that ESC had an advantage there. In contrast to the steady state tests like ECE R49 and ESC, the ETC is a transient cycle based on road-type-specific driving patterns of HD vehicles. It mainly consists of three equally divided modes (of 600 seconds each): urban (maximum speed 50 km/h, frequent starts, stops, and idling), rural (steep acceleration segment and average speed 72 km/h), motorway driving (average speed 88 km/h).

3. Real-world urban driving behaviour in India – New TERI study

Experiments were carried out in four Indian cities (Ahmedabad, Lucknow, Kolkata, and Patna,) to assess real-world driving conditions in different cities. While the four cities are the biggest in their respective States, they depict different characteristics. While, Ahmedabad is known for its new bus rapid transport system, Kolkata is heavily dependent on quite old buses, trams, and metro. Patna is the only city which is still complying with BS-III norms, while the other three have moved to advanced BS-IV regulations. Varying population densities, income profiles, climatic and geographical conditions, public transportation

[3] ESC test simulates high average load factors and very high exhaust gas temperatures

systems, and emission regulations in the four cities make it interesting to assess the driving conditions in different possible urban conditions in India. GPS (global positioning system) instruments were used to accurately collect the speed profiles of different categories of vehicles (two-wheelers, cars, and buses) in the cities. The surveys were carried out for more than 10 hours of drive covering different types of roads and area categories in the cities. However, it is to be noted that the survey does not includes driving outside dense, congested cities (driving on highways) and there could be higher emissions at higher speeds and accelerations on the highways.

Figure 2a shows the comparison of speed profiles of motor bikes observed in different cities with the IDC.

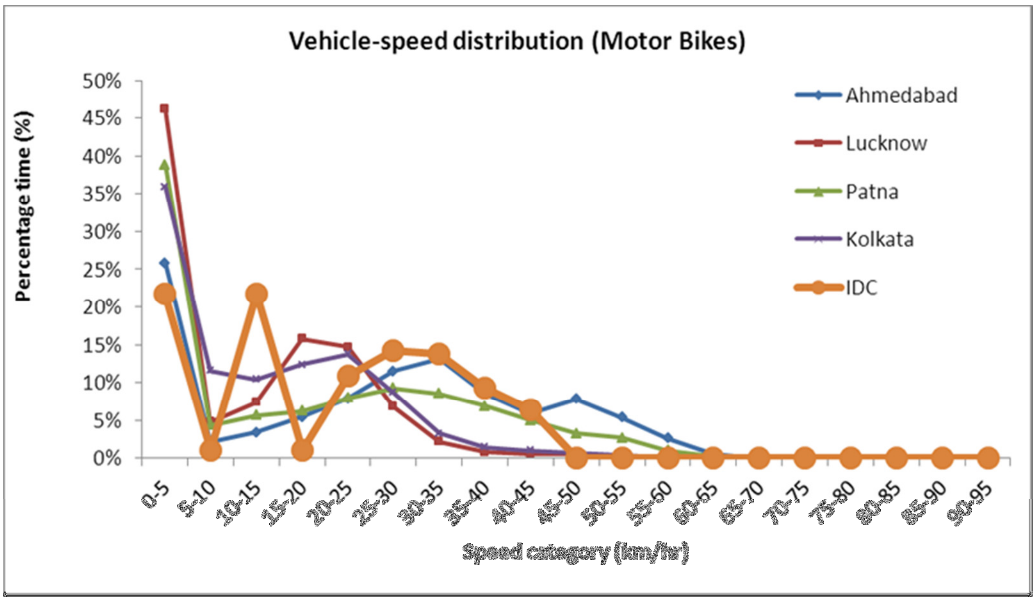


Figure 2a Comparison of speed profiles of two-wheeler motorbikes observed in different cities with the IDC

While there is a good match between the middle ranges of the speed profile, there is a clear mismatch at the extreme ends. Actual driving conditions in the cities clearly depict the presence of heavy congestion levels and hence reduced speeds. IDC allocates just about 20 per cent of its time weightage to these low speeds, which is found to be much higher in real world conditions due to congestion. On the other hand, high speeds achieved by the two-wheelers categories (although for much less time) are not addressed by the current IDC.

Figure 2b shows the comparison of on-road speed profiles of cars from the studies with the MIDC. While IDC did not account for very low and high speeds, MIDC accounts for these wider speed profiles and hence it is somewhat better suited cycle than the IDC in terms of speed profiles. MIDC is also significantly close to the idling conditions observed in real-world driving. However, the acceleration profiles of different cities are very different from the ones prescribed in MIDC. Figure 2c shows that MIDC does not account for high accelerations observed in the driving patterns of different cities. The speed-acceleration profiles are found to be considerably higher than MIDC in all the cities. Conclusively, the high power requirement zones, *i.e.*, accelerations happening at higher speeds, are not well reflected in the MIDC.

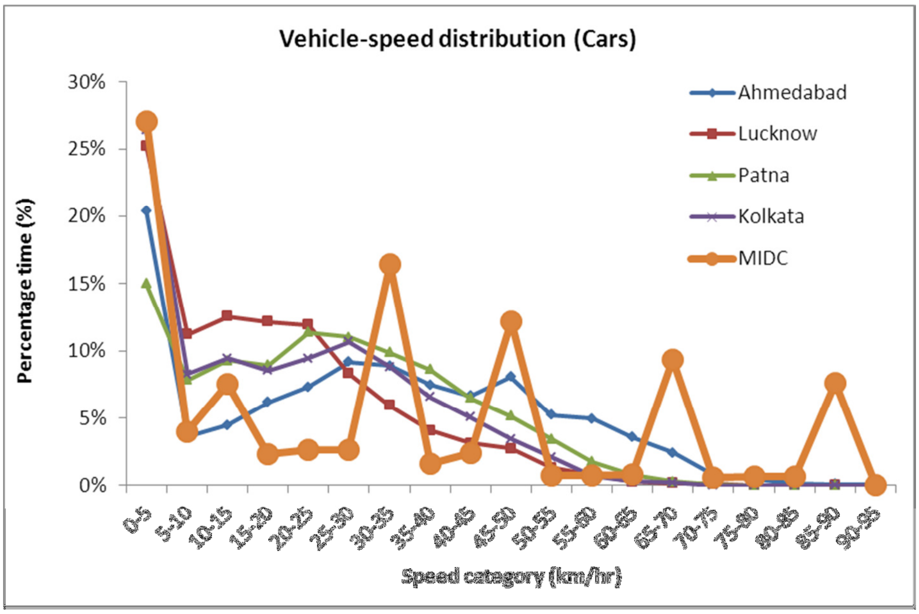


Figure 2b Comparison of speed profiles of cars observed in different cities with the MIDC

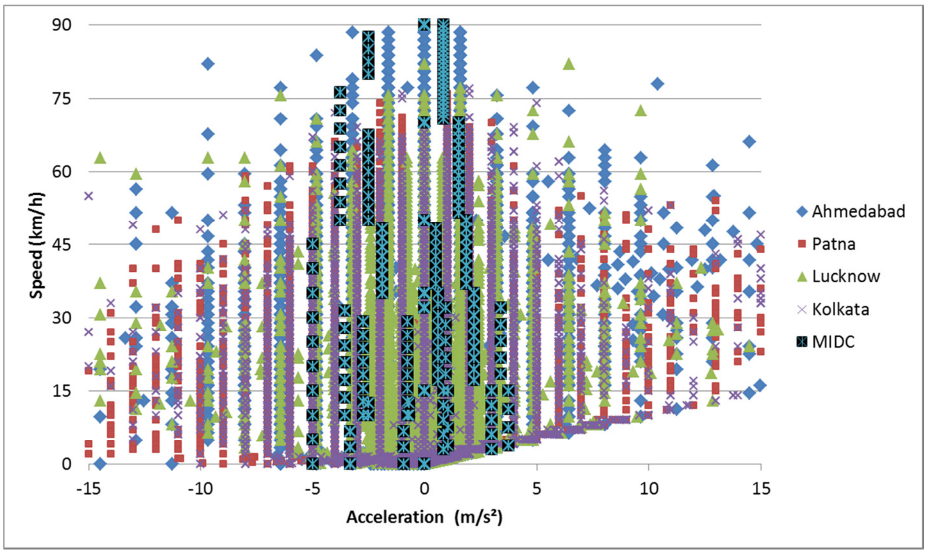


Figure 2c Comparison of speed-acceleration profiles of cars observed in different cities with the MIDC

Figure 2d shows the comparison of speed profiles of buses observed in different cities with the European test cycle (ETC) for heavy-duty vehicles. The observations taken in city shows the impact of congestion and very high percentage of time spent in low speeds. The urban component of the ETC cycle appears much closer to the real-world conditions (although not showing the best fit). Higher speeds observed in ETC cycle refer to highway driving.

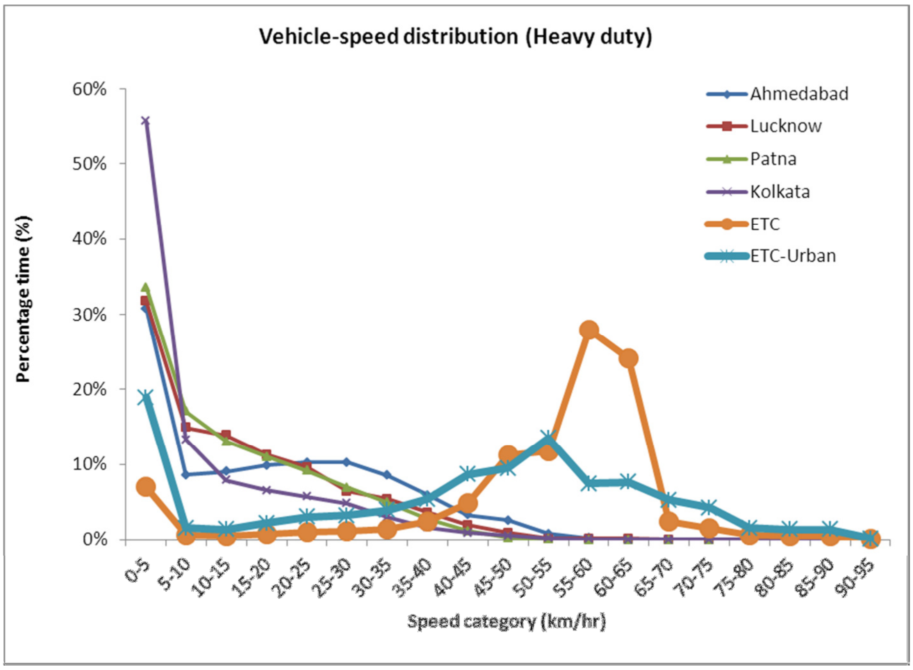


Figure 2d Comparison of speed profiles of buses observed in different cities with the ETC

The misrepresentation of real-world driving condition may lead to underestimation of emissions. Huang et. al., 2013 showed that a bus emits highest NOx in the high vehicle-specific power (VSP) and low-speed bin depicting starting and accelerating under heavy load conditions. Chen et. al., 2007 also showed the higher emissions during low speeds with frequent acceleration and decelerations. The results clearly show that test cycles do not cover the whole range of driving conditions and provide a window of escaping the emissions control by complying under the existing driving cycles but not effectively under real-world conditions. 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 inadequately covered by the test cycle.

4. Impact of non-representative driving cycles on emissions

The current driving cycles in India offer manufacturers the possibility of designing their emission control systems to comply only with the norms at specific test points lying within the test cycles while being less effective outside the cycle. Delphi, 2012 stated how cycle optimization appeared from Euro III by advancement of injection timing during transient operation and retarded timings retaining during steady states which leads to control of NOx emissions at specific points in the test cycles. There are many studies depicting the high pollutant emissions under real-world driving conditions despite the lowered emission limits worldwide (Table 2).

Table 2 Studies showing high emissions despite improvements in vehicular emission norms

Study	Relevant findings
Liu et. al., 2011	Increased NO(x) emission of buses by 60-120%. Inactivity of Selective Catalytic Reduction (SCR) under low exhaust temperature
JRC, 2011	Euro 3-5 NOx emissions (diesel vehicles) were 2-4 times higher under real-world conditions than under testing.
Carslaw et. al., 2011	Significant discrepancies between UK/European estimates of NOx emissions and those derived from the remote sensing data.
TNO,.2012	Euro V and EEV NOx emissions performance of HDVs does not guarantee low emissions in real world. Significant portion of vehicles show high NOx emissions under certain driving conditions.
Wang et. al., 2012	Limited impact of emission standards implemented in Beijing and nationwide on NOx emissions control
Huang et. al., 2013	NOx reduction efficiency of the SCR system in a Euro IV diesel bus strongly depends on driving conditions.
Chen, 2007	Real-world low-speed conditions with frequent acceleration and deceleration cause high emissions of CO and THC.
Wu et. al., 2012	No significant differences in NOx emission factors were observed between Euro II and III buses and between Euro IV (equipped with SCR systems) and Euro III buses. Real-time measurements suggest certification cycles did not reflect real-world conditions.

Figure 3 from JRC, 2011 shows that real-world NOx emissions are much higher than the emissions computed on the NEDC cycle in Europe.

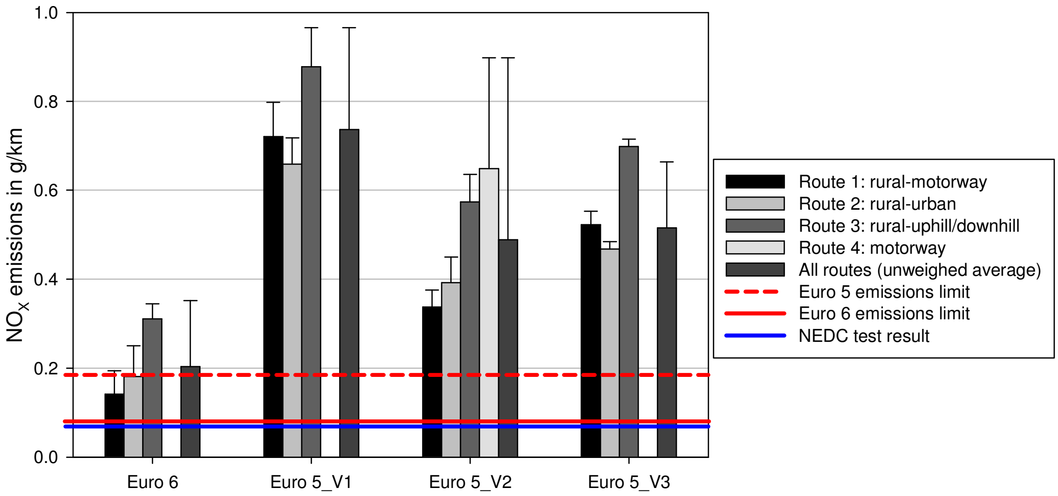


Figure 3 NOx emissions (g/km) under the NEDC test cycle and during real-world testing.
Source: Weiss et al, 2012

The results of Weiss et. al., 2012 also show that NOx emissions were many folds higher than what is observed on the NEDC cycle (Figure 4). This could be attributed to higher acceleration values under real-world driving. Figure 4 depicts that, while Euro 6 fared better than Euro 5 in controlling NOx emissions, in both cases real-world NOx emissions substantially exceeded type-approval test values.

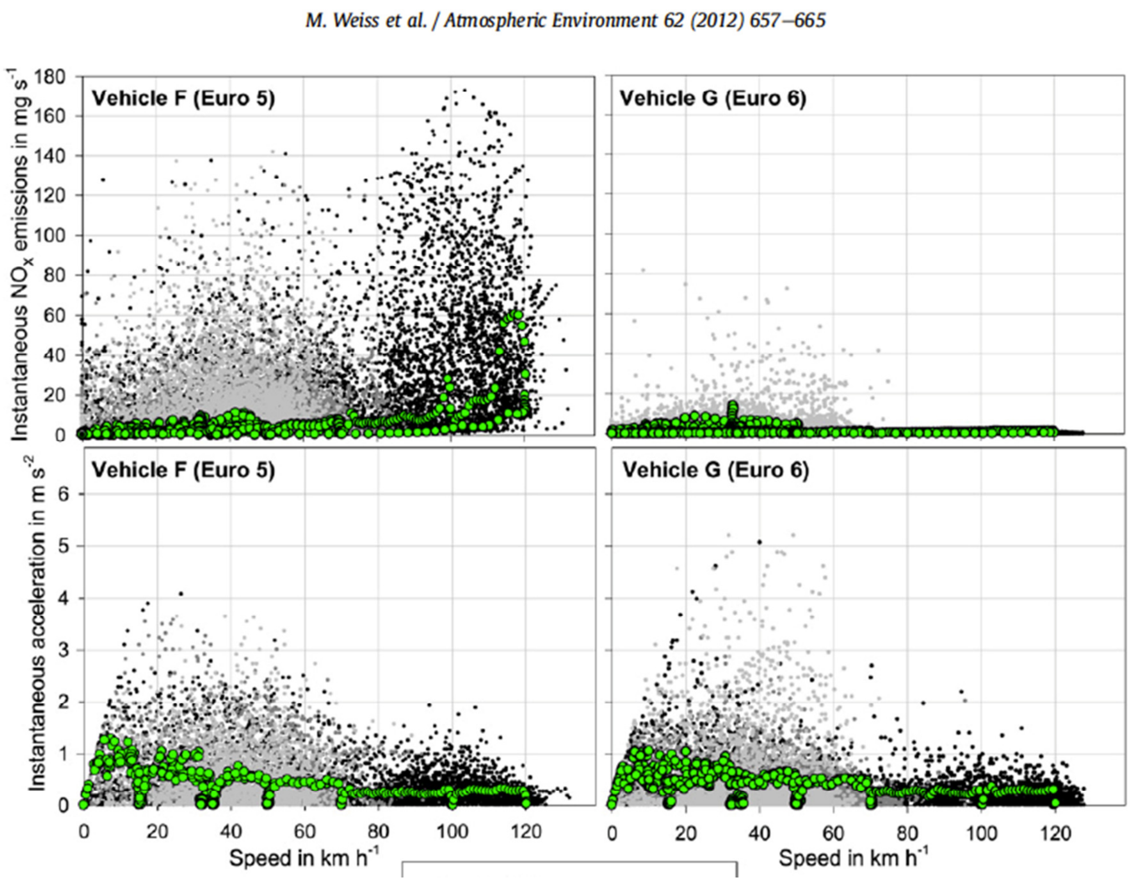


Figure 4 NOx emissions (mg/s) and acceleration profiles of a Euro 5 and Euro 6 car under the NEDC test cycle and real-world conditions in Europe
Source: Weiss et al, 2012
Note: Green dots are test emissions and black dots are emissions under real-world conditions.

Along with the impact on emissions, Mock et. al., 2013 also assessed the difference between the stated fuel economy and the ones observed during real-world driving in the US and Europe. The difference between the two was 10 per cent in 2001, which more than doubled to 25 per cent in 2011 coinciding with the establishment of mandatory CO_2 standards.

5. World Harmonized Test Cycles (WTCs)

In today's world of global markets, automobiles are internationally traded and hence require the type approvals according to local guidelines, which may lead to a duplication of efforts in modifying designs to acquire local approvals. To address this, many countries across the world are working together on a new world harmonized test procedure under the umbrella of The World Forum for Harmonization of Vehicle Regulations of the United Nations Economic Commission for Europe (UN/ECE/WP29).

These regulations aim to improve automobiles on various aspects such as like safety, environment, efficiency, and performance. India has already been a party to the UN Global Technical Regulations (GTR) since 2006 for the development of the World Harmonized Test Cycles (WTCs), which are being developed to closely mimic real-world driving conditions.

India has harmonized its emission norms for four-wheelers with European regulations and has adopted Euro 4 equivalent norms in 13 cities from 1 April 2010, and Euro 3 equivalent in rest of the country. India is already a party to 'The 98th Agreement' as it is a bit more flexible than the 58th agreement[4] for transposing an established GTR into a local regulation.

The WTCs are intended not only to improve the compliance of the emission control norms, but also to standardize the procedure at the global level, which is going to benefit the automobile manufacturers in the long run, eliminating the requirements of repetitive approvals and design modifications to comply with the regulations of individual countries.

WTCs, developed for various categories of vehicles, are discussed and compared against the existing cycles in India in the following section.

5.1 World harmonized motorcycle test cycle (WMTC)

The world harmonized motorcycle test cycle (WMTC) was developed under the umbrella of the UNECE. This cycle will be phased in for testing of two-wheelers in Europe. India also contributed to the process, and via a notification in June 2012 it introduced WMTC as an optional cycle for testing of BS III motorcycles. It is likely that the WMTC will become mandatory with the implementation of BS IV motorcycle emission standards after 2015. However WMTC is not yet applied for three-wheelers, which will continue to be tested on the IDC for now.

WMTC is composed of three different parts for three different categories of motorcycle as per their usage. The classification of the motorcycles and the driving cycles developed for them are shown in Table 4.

Table 4 Classification of the motorcycles and the driving cycles suggested in WMTC

[4] UNECE World Forum for Harmonization of Vehicle Regulations administered '58' Agreement in 1958 to include: (a) technical requirements and test methods by which performance requirements (to allow any technology) are to be demonstrated; (b) the administrative procedure for granting type approvals and their reciprocal recognition, including markings and conditions for ensuring conformity of production (COP). Some countries did not join the '58 Agreement due to disagreements on the mutual recognition. Thus, in 1998, in parallel to the '58 Agreement, the '98 Agreement concerning the establishing of global technical regulations (GTRs) was adopted.

Vehicle class	Cycle	Cycles	Time (s)	Distance (km)	Avg. speed (km/h)	Max. speed (km/h)	Red. speed (km/h)	Max. acc. (m/s^2)
1-1 and 1-2	Part 1s (cold and then hot condition)	Part 1	600	4.07/3.94	24.3	60	50	2.5/2.0
1-3	Part 1s (cold and then hot condition)							
2-1	Part 1 (cold) - part 2 (red. Speed-hot)	Part 2	600	9.11	54.7	94.9	84.9	2.69
2-2:	Part 1 (cold), part 2 (hot)							
3-1	Part 1 (cold), part 2 (hot), part 3 red. speed (hot)	Part-3	600	15.74	94.4	125.3	111.3	1.55
3-2:	Part 1 (cold), part 2 (hot), Part3 (hot)							

Class	Spec.
subclass 1-1	Engine capacity ≤ 50 cm^3 and 50 km/h < v_{max} ≤ 60 km/h
subclass 1-2	50 cm^3 < engine capacity < 150 cm^3 and v_{max} < 50 km/h
subclass 1-3	Engine capacity < 150 cm^3 and 50 km/h ≤ v_{max} < 100 km/h, but not including subclass 1-1
subclass 2-1	Engine capacity < 150 cm^3 and 100 km/h ≤ vmax < 115 km/h or Engine capacity ≥150 cm^3 and vmax < 115 km/h
subclass 2-2	115 km/h ≤ vmax < 130 km/h
subclass 3-1	130 ≤ vmax < 140 km/h
subclass 3-2	vmax ≥ 140 km/h

At this moment the vehicles < 50 cc & Vmax < 50 km/h are not classified in any of the categories. Figure 5 shows the speed variations under the different cycles and their comparisons with the IDC. It can be adjudged that WMTC covers a wider range of speed variations and considers different categories of two-wheeler vehicles.

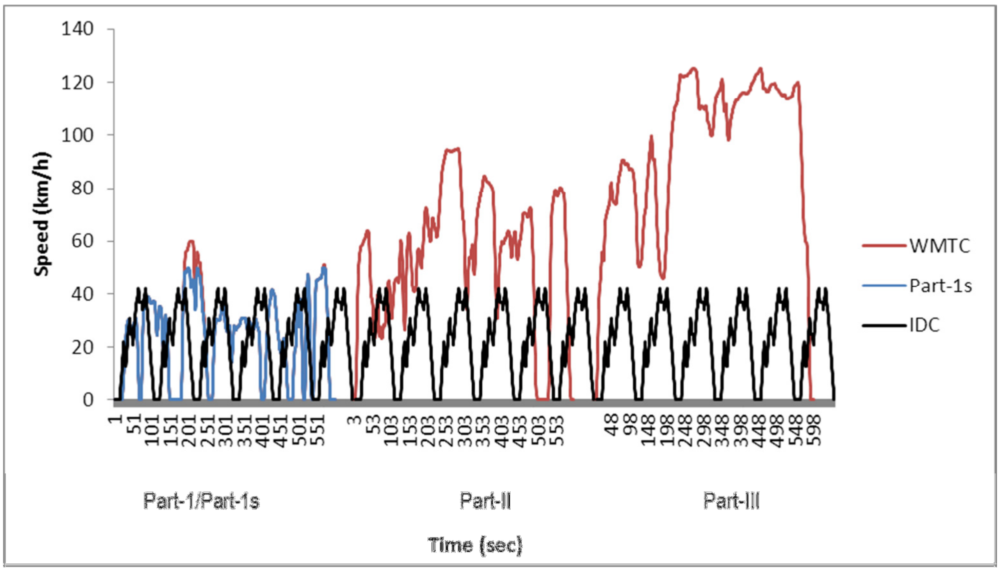


Figure 5 Speed variations in different WMTC cycles for two-wheelers compared with the IDC

The speed-acceleration test points followed in IDC are also compared with WMTC, which also shows that WMTC test procedure covers a wide range in comparison to IDC (Figure 6).

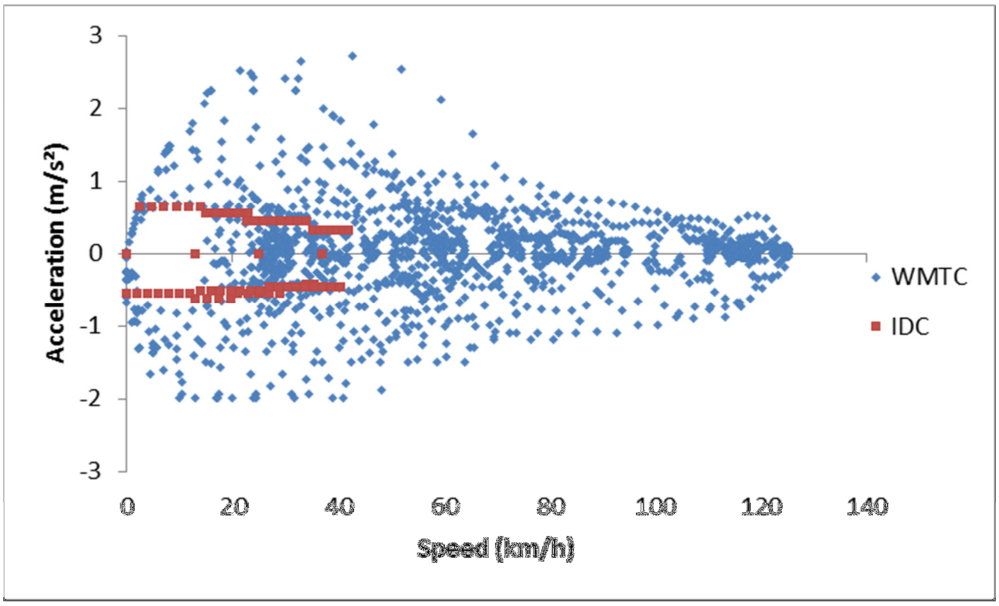


Figure 6 Comparison of speed-acceleration test points followed in IDC and WMTC for two-wheelers

IDC is applicable to all types of two-wheeler vehicles, while WMTC has three different categories (Class 1, 2, and 3) based on CC and max speed. The cycles followed in WMTC cover wide ranges of speed-acceleration profiles and, hence, allows for better compliance of emission norms in varying driving conditions. At present, WMTC has not been suggested for three-wheelers, but the same IDC used for two-wheelers has been applied to three-wheelers. A certain percentage of driving time has been observed to be in the high-speed range (>50 km/h) which is covered in WMTC but not in IDC. WMTC specifies cold-start condition as opposed to warm-start testing suggested in IDC.

It should be noted that India is part of the UNECE informal group to expand the use of WMTC from motorcycles to mopeds and three-wheelers. The group for Environmental and Propulsion Performance Requirements (EPPR) was created in 2012 and is expected to present a regulatory proposal by 2016. The EPPR proposal intends to cover tailpipe emissions under WMTC for moped and three-wheelers, in addition to motorcycles, and also include durability, OBD, evaporative tests, and fuel consumption/CO_2 emissions.

5.2 Worldwide harmonized light-duty test procedure (WLTP) (for cars)

The Worldwide Harmonized Light Vehicles Test Procedure (WLTP) is being developed by experts from the European Union, Japan, and India under guidelines of UNECE. It is a global harmonized standard for testing of vehicular emissions (air pollutants and GHGs) and fuel efficiency. This procedure has the aim to replace the NEDC procedure for testing of light-duty vehicles in Europe. WLTP consists of three cycles based on categorization of different light-duty vehicles as per the PMR (rated power (W) curb mass (kg)) ratio. The cycles are also defined based on the maximum speed declared by the manufacturer. Table 5 shows the three test cycles which can be selected based on different vehicles categories.

Table 5 WLTP Test Cycles for light duty vehicles

Class	PMR	Power category	Remarks
Class 3	PMR > 34	Low, Middle, High, Extra-High	If v_max < 135 km/h, phase 'extra-high' is replaced by a repetition of phase 'low'.
Class 2	34 ≥ PMR > 22	Low, Middle, High	If v_max < 90 km/h, phase 'high' is replaced by a repetition of phase 'low'.
Class 1	PMR ≤ 22	Low, Middle	If v_max ≥ 70 km/h, phase 'low' is repeated after phase 'middle'. If v_max < 70 km/h, phase 'middle' is replaced by a repetition of phase 'low'.

Source: www.unece.org

Figure 7a and 7b show the speed and acceleration profile suggested in the WLTP. Note that the acceleration rates in Figure 7b are associated with the speeds in Figure 7a. Class 3 procedures are suggested for high powered vehicles representative of vehicles driven in Europe and Japan. Class 2 and 1 procedures are defined for vehicles representing the Indian fleet. Low PMR vehicles are subjected to a maximum speed of 64.2 km/h, while class 2 vehicles will be tested on a maximum speed of 85 km/h. Lower accelerations are suggested in class-I vehicles (< 0.76 m/s^2), which go up to 1.58 m/s^2 in case of Class-III vehicles.

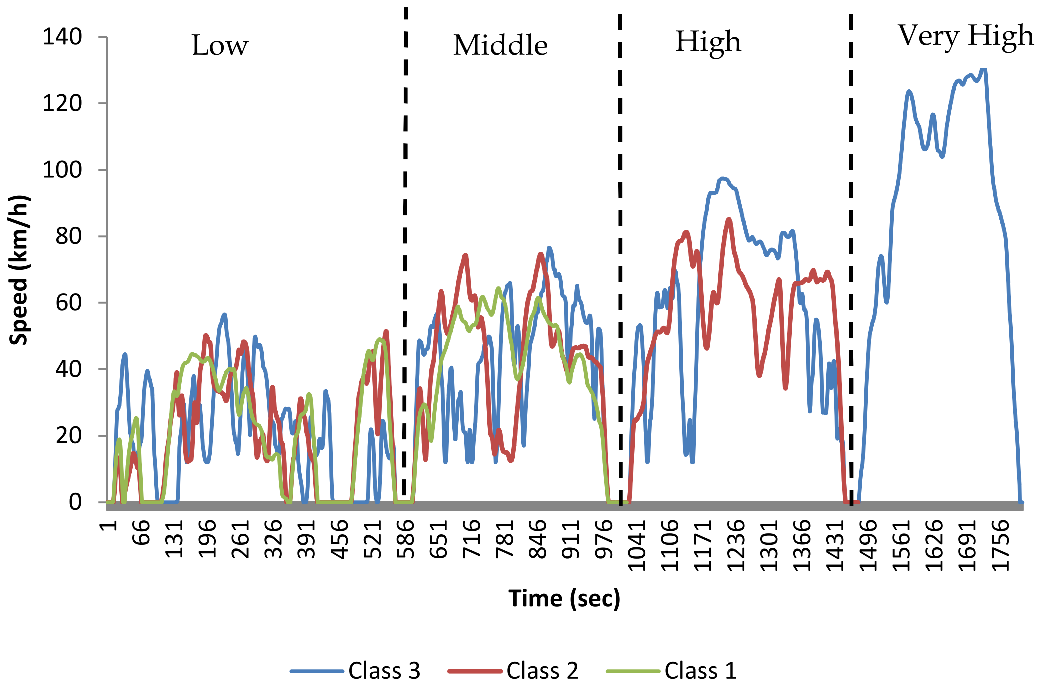


Figure 7a Speed profiles suggested in the WLTP for different classes of light duty vehicles (cars)

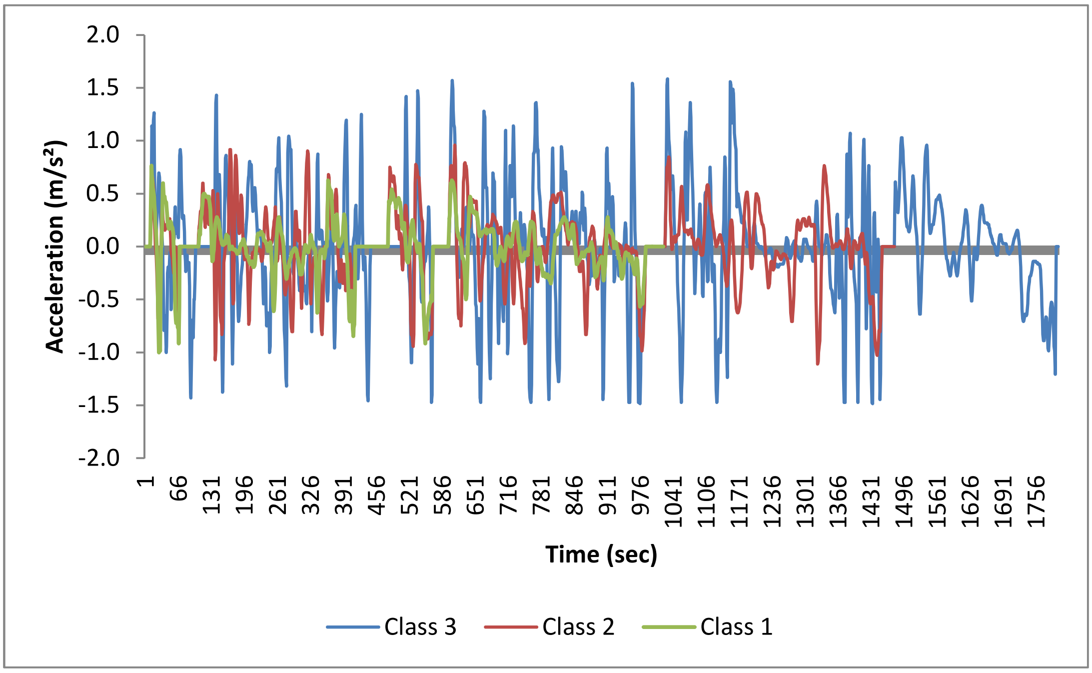


Figure 7b Acceleration profiles suggested in the WLTP for different classes light-duty vehicles (cars)

Data source: www.unece.org

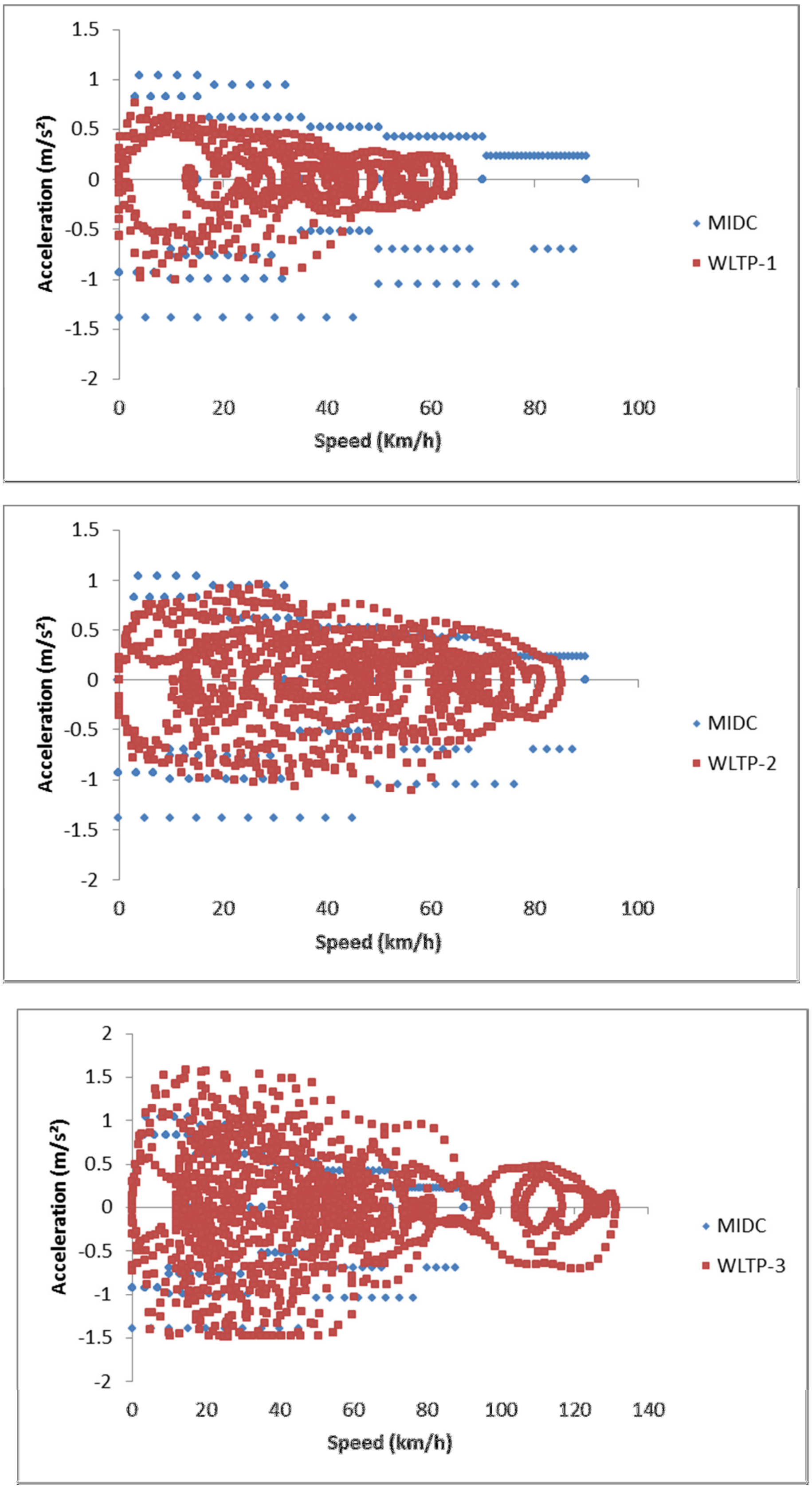


Figure 8 a-c Speed-acceleration scatter plots for MIDC and WLTP (Class-I, II, and III)

Data source: www.unece.org (WLTP cycle)

Figures 8 a to c show the coverage of MIDC and the WLTP cycles on speed-acceleration profiles. It can be deduced from the figure that WLTP is a more exhaustive cycle and covers many more data points so that it will require more robust emission control systems that work better in the real world. Moreover, it is also based on power to mass ratios and hence customised for different weight categories within the light-duty vehicles.

5.3 World harmonized cycles for heavy duty vehicles

For heavy-duty diesel engines, GTR has defined two sets of cycles. These two are: i) a hot-start steady-state test cycle (WHSC), and ii) a transient test cycle (WHTC) with both cold and hot start.

5.3.1 World Harmonized Stationary Cycle: WHSC for heavy duty vehicles

The WHSC test is a steady-state engine dynamometer test procedure developed based on actual driving conditions observed in several world regions like EU, USA, Japan, and Australia. The idea is to take into account regional variations in the driving conditions. The difference between the two cycles is shown in Figure 9.

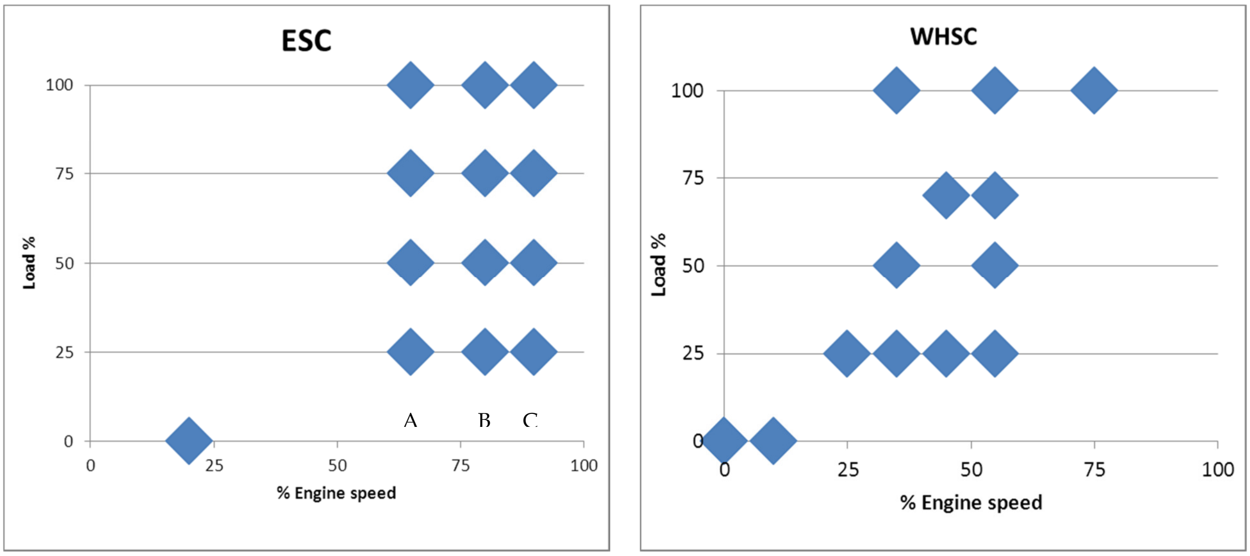


Figure 9 Engine testing points in the ESC and WHSC cycles

Data source: Delphi, 2012

The comparison of the two cycles clearly shows that, while testing on ESC cycles is done on three speed variations, WHSC covers five different speeds while testing different load patterns. WHSC is a ramped steady-state test cycle, consisting of a sequence of steady-state engine test modes and defined ramps in between.

5.3.2 World Harmonized Transient Cycles- WHTC for heavy duty vehicles

The WHTC test is a transient heavy-duty engine dynamometer test procedure developed by UNECE for emission testing of heavy-duty vehicles. It is a transient test of 1800 second duration, covering varying driving modes. Speed variations included in the WHTC and ETC are compared in Figure 10. WHTC actually has a lower average cycle work than ETC as lower speeds and loads have been assumed in this.

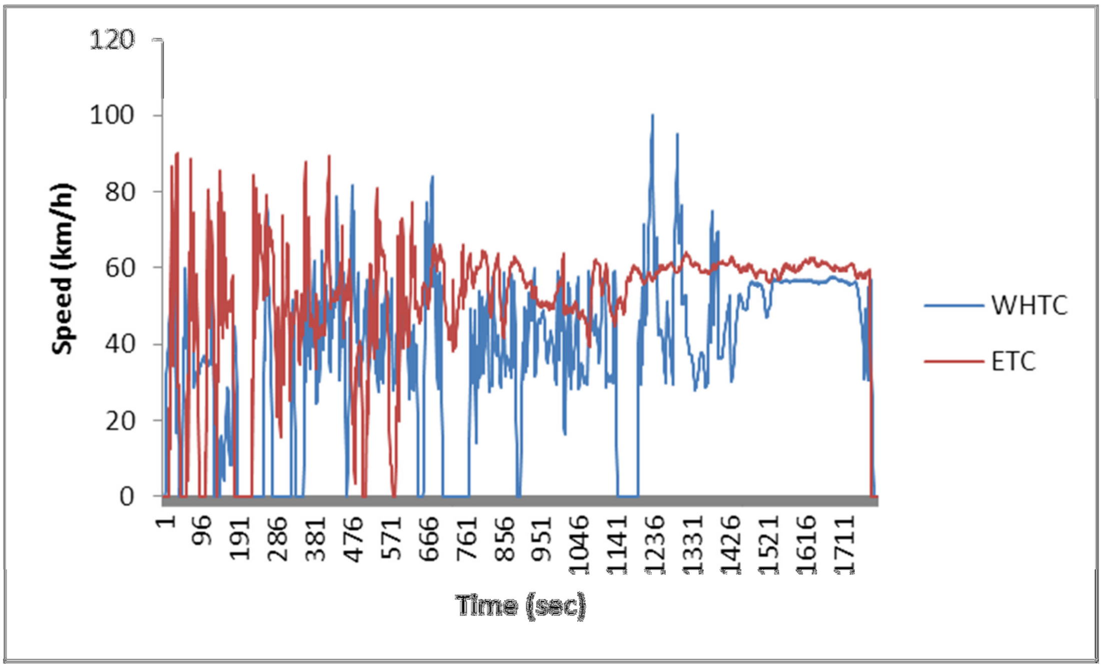


Figure 10 Comparing speed profile in the WHTC and ETC prescribed for heavy-duty vehicles

Figure 11 shows the speed-torque testing points in the WHTC and ETC cycles, which also suggests that WHTC accounts for wider ranges of torque values than ETC. Wider ranges of torque and speeds which were not well represented in ETC are now included in the WHTC.

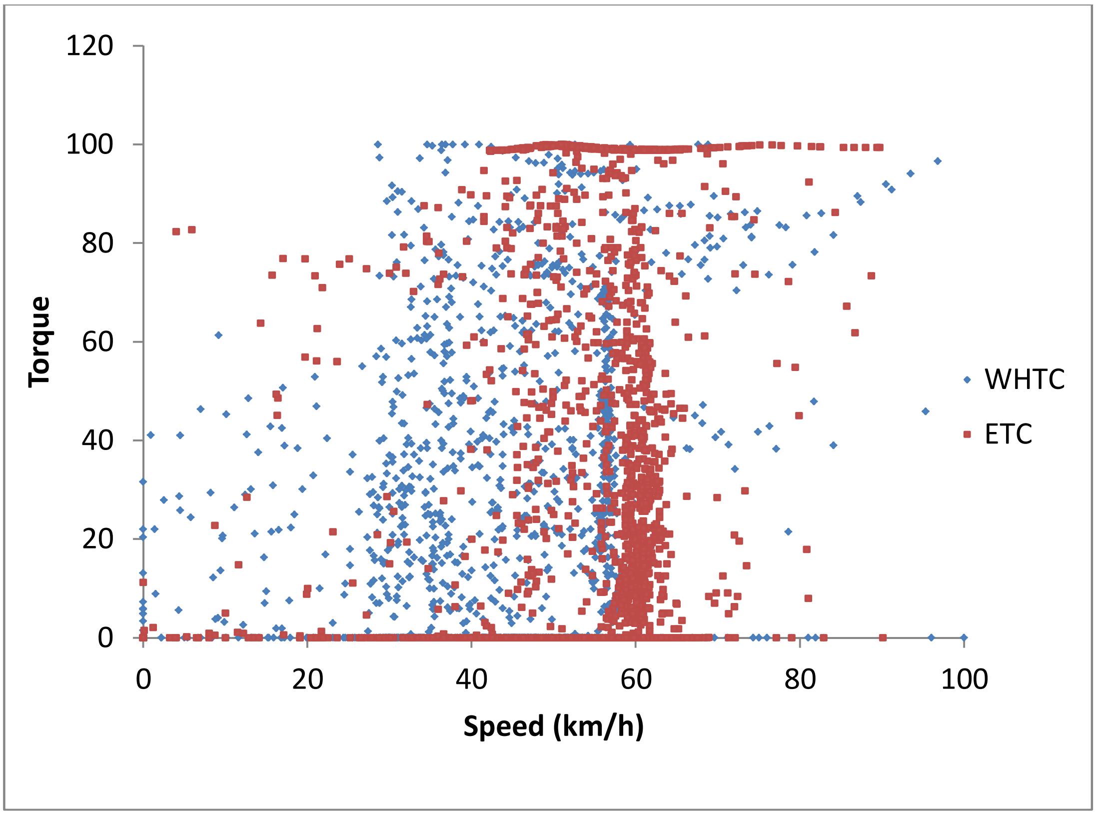


Figure 11 Comparing speed-torque testing points in WHTC and ETC

The main advantage of WHTC procedures is that they cover a wider range of driving conditions, and, hence, ensure lower emissions during real-world driving. Moreover, in contrast to ETC procedures, the testing is done under both hot and cold start conditions in WHTC. One of the advantages of WHTC is that HD vehicles will also be tested under low-speed conditions (typical of urban driving), which could effectively test the efficiency of SCR systems under unfavourable conditions.

5.4 Advantage of World Harmonized Test Cycles

World harmonized test cycles have a clear advantage over currently used driving cycles in that they are more comprehensive and cover a wider variety of actual on-road conditions, and hence present a better real-world representation. These cycles could also eliminate the need for multiple testing required due to different regulations in different countries. The most important advantage of these cycles is that their wider speed and load points significantly reduce the possibility of a vehicle passing the emission tests while emitting substantially more than the legal limits under real-world driving conditions.

Automobile manufacturers may also benefit from the adoption of world harmonized cycles, as the R&D costs on the test cycles for each country/region can be eliminated. This will lead to easy inventory of fewer parts for different models of vehicles. This can allow the manufacturers to design vehicle-parts with minimal differences which could enhance the quality with minimum defects. This leads to global manufacturing standardization and improved logistics. Eventually, this allows the manufacturers to build/design differentiated products in much faster and cheaper ways.

6. Conclusions and recommendations

The World Forum for Harmonization of Vehicle Regulations (WP.29) offers environmental and trade benefits for globally harmonized regulations on vehicles. India, being a party to the 1998 Agreement, has to ratify it by adopting WLTP and WHDC. WMTC has already been nominated as an optional cycle to be used for two-wheelers. However, no decision has been made on the WLTP and WHDC cycles. There is a clear need for adoption of test cycles that are more representative of real-world driving conditions, thus ensuring better compliance of the environmental norms during real-world driving and improving air quality.

India is in a situation to decide about the future progression of emissions control and fuel quality norms in the country. The advancement of vehicular emissions norms will reap limited benefits unless current test cycles are revised. Experience in the developed world (Europe) and developing countries like China has shown that real-world emissions could be much higher than those expected from type-approval results. As huge investments are about to be made in the sector, it is imperative to take into account the benefits of adopting world harmonized test cycles. Initially, world-harmonized test cycles could be made optional for testing for a few years to give ample time to the manufacturers to adapt to them. World-harmonized test cycles should then become mandatory. India has already followed this procedure for motorcycles without much delay in tighter emission standards. It can do the same for other vehicles.

Europe is the in process of making a decision on the adoption of these cycles for vehicle type-approval. Hence, in the long run, India could follow the European legislation, which could be made mandatory for the next levels (Euro 6 onwards) of vehicular emissions control norms in a gradual manner. Currently, air pollution issues of fuel quality, vehicular emission norms, and driving cycles are being dealt with at different ministries. There is probably a need for an agency that can have a holistic view of the problem and regulate fuels and vehicle standards appropriately to help meet the desired air quality standards in the urban centres of the country. This was previously recommended by the 2002 Auto Fuels Policy Committee.

There is a need to shift the focus of the current regulations from mere laboratory testing of the controls to the real-world emissions performance. This is will ensure the long-term compliance of stated emissions control norms in real world conditions. These procedures are already being prepared in Europe for the type approval and in-service conformity testing of all light-duty vehicles (EU, 2013). The adoption of better driving cycles may also need to be coupled with a strong recall policy; *i.e.*, testing of vehicles beyond type-approval and conformity to production procedures to ensure the compliance throughout the life-cycle of the vehicles.

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