EPCA Report No 99

Recommendation for an implementation plan for use of remote sensing for on-road emissions monitoring as per directions of the Hon'ble Court on 8.7.2019

July 26, 2019

In the context of the on-going deliberations on the potential application of remote sensing technology for monitoring on-road vehicular emissions, the Hon'ble Supreme Court has directed Environment Pollution (Prevention and Control) Authority (EPCA) as follow:

> "With respect to remote sensing technology a report has been filed by International Centre for Automotive Technology (ICAT). It is pointed out by Amicus Curiae that remote sensing technology has been found to be helpful in reducing the pollution level and it is a finding of the ICAT that it is effective method to check pollution. As to put it into operation, time prayed on behalf of the EPCA to consider and submit a report. As the matter is urgent and is in connection with the reduction of pollution, we grant only fifteen days time to the EPCA to submit a proposal after consulting various stakeholders."

In view of this direction from the Hon'ble Supreme Court, EPCA convened a meeting on July 16, 2019 with all concerned agencies including the Union Ministry of Road Transport and Highways (MoRTH) and Transport Department of National Capital Territory of Delhi to identify the key steps needed for implementation.

EPCA has detailed out the steps that are required for implementation and identified the agencies and schedule for action. **The Hon'ble Supreme Court is requested to direct the agencies as detailed in the plan (page 9) to undertake the outlined work so that remote sensing technology can be deployed for checking pollution from vehicles.**

1. Steps to be taken by Union Ministry of Road Transport and Highways (MoRTH)

1.1 Define the scope and role of remote sensing programme vis a vis on-going pollution control certificate (PUC) programme: The Ministry of Road Transport and Highways needs to frame rules under Central Motor Vehicle Act and Rules to define the scope and use of remote sensing programme for monitoring and enforcement of on-road emissions. This needs to state how this would co-exist with the ongoing pollution under control certificate (PUC) programme for physical checking of emissions. Both the programmes have different objectives and scope but they are complimentary and this needs to be clarified. While under the PUC programme periodic physical checks of exhaust emissions from vehicles will continue to assess compliance with limits imposed on idling emissions, remote sensing programme will screen vehicles on the road to identify gross or very high emitters. Catching and removing the worst polluters on the road can give substantial emissions benefit. It is possible that some vehicles may escape or even pass PUC tests and yet experience technical anomalies that may make them high emitters between two scheduled PUC tests. Moreover, PUC is not a very effective way of assessing real magnitude of emissions from vehicles.

Adding remote sensing test has become necessary as PUC is a very simple and basic test that lacks quality control and is not appropriate for screening vehicles with more advanced emissions control systems as under BSIV and BSVI regime. Not only do the results of these tests do not correlate well with dynamometer tests (that are used at the time of vehicle certification), they are also increasingly not reliable for BS IV and beyond vehicles. They also fail to capture NOx emissions which contribute to ozone formation, and contribute to secondary particulate matter formation. It may be noted that as present, the PUC program relies upon idle speed testing mode for petrol/LPG/CNG vehicles and free acceleration mode (FAS) or smoke opacity test for diesel vehicles. These tests measure carbon monoxide (CO), and hydrocarbon (HC) concentration in exhaust from petrol/LPG/CNG vehicles, and peak smoke opacity for diesel vehicles that is meant to be a proxy for particulate emissions. If vehicles tested cross the prescribed limit values, they have to go for repair.

Rules to be defined by MoRTH will make it clear that remote sensing can be used to identify vehicles which in all probability have either a defective

emissions control system or one that has been tampered with. The big advantage of remote sensing is that it can be carried out in a non-intrusive fashion, and without vehicles having to report physically to centralized test center or PUC stations. The same remote sensing setup can be used to measure emissions from different vehicle types and evaluate hundreds to thousands of vehicles each day.

The purpose of remote sensing as opposed to PUC will be to identify only a limited number of vehicles identified as high emitters that can then be selectively required to report for a more improved loaded test at centralized, and possibly automated testing centers. ICAT report has also recommended a loaded test. As a result, a remote sensing program can dramatically improve the effectiveness of inspection and maintenance program.

This programme will also have to be aligned with further upgradation of the centralized inspection and maintenance centres that have come up in Jhuljhuli and Burari in Delhi. These can be equipped with simple dynamometers to measure emissions like NOx and others that is not possible under PUC. These measurements are possible in loaded tests that are more capable of identifying high emission malfunctions as the air-fuel control and emission after-treatment systems evolve. The loaded tests are carried out on a dynamometer, and thus require centralized testing centers. However, it is not possible to test each and every vehicle in the fleet to identify gross polluters due to the sheer number of vehicles involved. For this purpose, commercial vehicles can be prioritized for further tests in these centers. Personal vehicles will have to be issued challans to be taken for repair in workshops.

Eventually, a remote sensing program can also be used support a "clean screen" program that lets drivers skip a periodic tailpipe emissions recertification test by verifying that their vehicle emissions are within a limit range. Real-world emissions factors developed using remote sensing can significantly improve the accuracy of outputs of emissions models, and air-quality forecast tools.[1],[2]

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[1] https://theicct.org/publications/remote-sensing-briefing-dec2018
[2] ICAT 2019, New Delhi Real World Emission Study (NDRWES) using remote sensing technology, Final Report submitted to Ministry of Heavy Industries and Public Enterprises, GOI, February

Figure 1: Approaches to remote sensing measurements
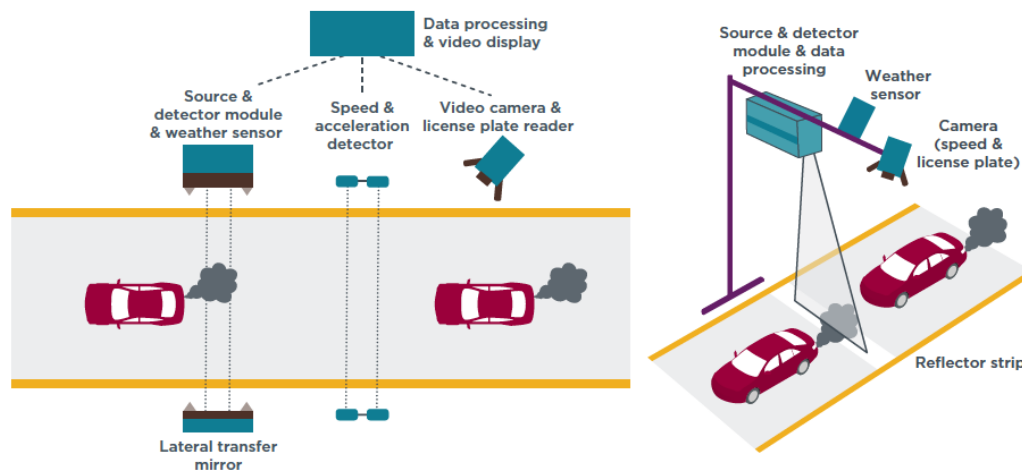
Source: ICCT 2019, Worldwide use of remote sensing to measure motor vehicle emissions

Notification of enforcement actions: MoRTH would need to specify deterrence for these vehicles for effective enforcement. It is recommended that MoRTH should notify that insurance coverage of vehicles that are identified as gross polluter under the remote sensing program should be revoked in 30-60 days unless the vehicle has undergone repairs and if a commercial vehicle has passed the advanced test including loaded mode test at Jhuljhuli or other preferably automated I/M stations.

The notification should specify that passing of PUC tests under idle mode will not be a reason to invalidate the gross polluter identification by remote sensing. The notification should clarify that traffic police may stop and inspect vehicles if they have been found to fail the high emitter thresholds in remote sensing measurements.

1.2 Notification of gross polluter thresholds, and enforcement action under Central Motor Vehicle Rules: MoRTH may take on board the recommendation of the ICAT report that recommends setting of a pollutant-specific cut point per fuel-type, technology group, and/or Bharat emission norms. These cut-points as specified in the ICAT report should be notified by MoRTH as threshold limits for catching highly polluting vehicles on road. A high threshold (e.g. 99th percentile of values in ICAT report) should be classified as "Extreme polluters", and a moderately high

threshold (e.g. 95th percentile of values in ICAT report) should be classified as "high emitters" as shown in table 1 and table 2.

Table 1: Cut-points for Extreme Polluters

Vehicle Type	CO Percent	HC ppm	NO ppm	UV Smoke
HDV	3.637	2258	3966	1.517
LDV	2.752	1356	2223	0.608

Table 2; Cut-points for High Emitters

Vehicle Type/Fuel/Bharat Stage	CO Percent	HC ppm	NO ppm	UV Smoke
HDV/Diesel/Bharat St IV	1.377	1104	2685	0.766
LDV/Diesel/Bharat St IV	0.617	385	1508	0.335
LDV/CNG-Petrol/Bharat St IV	1.259	631	1399	0.099
LDV/Petrol/Bharat St IV	0.92	561	766	0.083

Note: ICAT needs to work out similar cut-points for BSI, BSII, BSIII vehicles based on their RSD testing.
Source: ICAT Report, 2019

The suggested cut-points can be adopted at the start of the programme and revised after 12 months based on collected data (see Annexure 1 for details)

1.3 Issue guidance on industry standard on remote sensing: Ministry of Road transport and Highways would need to provide a technical guidance on remote sensing equipment, remote sensing data reporting which specifies design, construction, networking and data sharing of motor vehicle. Remote sensing monitoring platform will have to developed to allow broader adoption of remote sensing beyond Delhi. The standard should also include technical requirements related to remote sensing location selection, construction, operation and maintenance.

2. Steps to be taken by the Department of Transport, NCT Delhi

Department of Transport, NCT Delhi should be responsible for implementation of the programme in the city. Once successful, transport departments of other NCR districts can be directed to implement similar programmes. The Department of Transport, NCT Delhi needs to do the following:

2.1 Issue global tender for procurement of remote sensing equipment and its operations: A global tender should be issued within three months to procure five remote sensing setups immediately as suggested in the

ICAT report. Ten additional setups should be procured after the first five units have been operational for a full year. The systems should be capable of measuring NO, NO_2, HC, CO, CO_2, and opacity at a minimum. The operator of equipment should be asked to procure data processing hardware and necessary software needed to operationalize the remote sensing equipment and linking it with the centralized database.

Availability of equipment: According to data sourced from the International Council on Clean Transportation[3], there are at least half a dozen manufacturers of remote sensing equipment globally. US companies first manufactured and commercialized this equipment. But currently, Chinese authorities test far more vehicles using remote sensing than US or Europe. Chinese companies are also manufacturing this equipment (see table on equipment).

Table 1: Main remote sensing technologies and manufacturers.

Type	Position	Provider / Inventor	Equipment name	Measurement	Measures
Open path	Cross-road	University of Denver	FEAT	Arc lamp light beam with mirror reflector	CO, HC, CO_2, NO, NO_2, NH_3, SO_2, opacity
	Cross-road	Opus	RSD 4600 and older	Arc lamp light beam with mirror reflector	CO, HC, CO_2, NO, opacity
			RSD 5000		CO, HC, CO_2, NO, NO_2, NH_3, opacity
	Cross-road	Environmental Technology Consultants	R-series S650	Arc lamp light beam with mirror reflector	CO, CO_2, HC, NO, NO_2
	Cross-road; Overhead	Dopler Eco Technologies	DPL7000 Series	Laser light beam with mirror reflector	CO, CO_2, HC, NO, opacity
	Overhead	HEAT LLC	EDAR	Laser curtain with strip reflector	CO, total and speciated HC, CO_2, NO, NO_2, opacity
	Overhead	Anhui Baolong		Arc lamp light beam with mirror reflector	CO, CO_2, HC, NO, opacity
Extractive	Overhead sampling	University of California, Berkeley		Exhaust plume sample	CH_4, NO, NO_2, NH_3 BC, PM, PN, PN size,
	Overhead sampling	CARB	Portable Emissions Acquisition System (PEAQS)	Exhaust plume sample	Black carbon and NO_x
	Overhead sampling in Shed	University of Denver	OHMS	Exhaust plume sample	CO, CO_2, HC, NO, NO_2, N_2O, PM, PN, Black Carbon
	Roadside sampling	Czech Technical University		Exhaust plume sample	CO, CO_2, NO_x, PM, PN
	Roadside sampling	University of Münster		Exhaust plume sample	NO_x, CO_2, PN
	Plume chaser	University of Heidelberg	ICAD	Exhaust plume sample	NO, NO_2, CO_2
	Plume chaser	University of Birmingham	SNIFFER	Exhaust plume sample	NO, NO_2, CO_2
	Plume chaser	CARB	Mobile Measurement Platform (MMP)	Exhaust plume sample	CO, CO_2, HC, NO_x, PM, PN, Black Carbon

Source: ICCT 2019, Worldwide use of remote sensing to measure motor vehicle emissions

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[3] https://theicct.org/publications/worldwide-use-remote-sensing-measure-motor-vehicle-emissions

2.2 Do a site selection and sampling plan: Delhi transport department should assess site selection and sampling plan for remote sensing. This has strong bearing on emissions. EPCA is recommending that the sites for use of this equipment could be at the entry to Delhi, to check on emissions from heavy-duty vehicles.

2.3 Set up system for management of data and network: The data processing system for remote sensing consists of telemetry equipment, display equipment, data server, video data server, backup server, router, network printer, mobile workstation, firewall, etc. The data collected from remote sensing should be stored in secure locations, and linked with the VAAHAN database so that detailed vehicle details could be obtained on the basis of license plate. Further, the software should automatically issue a warning to all vehicle owners whose vehicles exceed high emitter threshold even once. If the vehicle in question is deemed to be a high emitter or an extreme polluter, then a challan through the Delhi police e-challan system should be issued. National Informatics Centre (NIC) may be asked with development of the integrated platform necessary for this purpose with key operational and legal inputs from Delhi Traffic Police. Consistent with the Open Government Data (OGD) initiative, a version of the emissions data, without the license plate and vehicle owner details, but identifying the make, model, fuel type, and year of vehicle should be released to the public so that researchers may be analyze the data for trends in vehicle emissions, and/or identify systemic problems with vehicles of certain make or type.

Further technical details needed for implementation are summarized in Annexure-I.

3. **Proposed plan for implementation of remote sensing for pollution testing of vehicles in the city submitted for the consideration of the Hon'ble Supreme Court**

The objective is to identify and penalize gross polluters – vehicles with high pollution levels. Many countries in the world are using this technology to combat pollution from vehicles (see table below)

Table 2: Overview of the different remote sensing technologies, type of vehicles measured, and programs that took place in different countries since 2010.

Country	Technology				Type of vehicles measured					Use of remote-sensing					Number of individual measurements since 2010
Argentina	C				PC	LCV	HDV	MC			MO				10,000 - 100,000
Australia	C				PC	LCV	HDV			R	MO				10,000 - 100,000
Austria	C				PC	LCV	HDV			R	MO	H			10,000 - 100,000
Bulgaria	C				PC	LCV	HDV	MC			MO	H			10,000 - 100,000
Canada	C	O	A		PC	LCV	HDV			R	MO	H		MS	10,000 - 100,000
Chile	C				PC	LCV	HDV	MC			MO				10,000 - 100,000
China	C	O		S	PC	LCV	HDV			R		H			>1,000,000
Colombia	C				PC	LCV	HDV	MC			MO				10,000 - 100,000
Czech Republic			A		PC	LCV	HDV	MC	OFF	R					10,000 - 100,000
Denmark	C				PC	LCV	HDV			R	MO	H			10,000 - 100,000
Finland				S			HDV			R					<10,000
France	C	O			PC	LCV	HDV	MC		R	MO				100,000 - 1,000,000
Germany	C		A	S	PC	LCV	HDV	MC		R	MO	H		MS	10,000 - 100,000
Ghana	C				PC	LCV	HDV	MC		R	MO				10,000 - 100,000
Hong Kong	C				PC	LCV	HDV			R	MO	H		MS	>1,000,000
India	C				PC	LCV	HDV	MC		R	MO				>1,000,000
Iran	C				PC	LCV	HDV			R	MO	H			10,000 - 100,000
Japan	C				PC	LCV	HDV	MC			MO				100,000 - 1,000,000
Korea	C				PC							H			>1,000,000
Mexico	C		A	S	PC	LCV	HDV	MC		R	MO	H	L		100,000 - 1,000,000
New Zealand	C				PC	LCV	HDV								100,000 - 1,000,000
Slovenia				S	PC	LCV	HDV			R					<10,000
Spain	C				PC	LCV	HDV	MC		R	MO	H			>1,000,000
Sweden	C		A		PC	LCV	HDV			R	MO				10,000 - 100,000
Switzerland	C				PC	LCV	HDV	MC		R	MO			MS	100,000 - 1,000,000
UK	C	O		S	PC	LCV	HDV	MC		R	MO			MS	100,000 - 1,000,000
USA	C	O	A	S	PC	LCV	HDV	MC	OFF	R	MO	H	L	MS	>1,000,000

C: Cross-road (open path) system
O: Overhead (open path) system
A: Extractive air sampling at a fixed location
S: Extractive air sampling from a car (plume chaser or sniffer)
PC: Passenger Car
LCV: Light-commercial vehicles, such as vans and pickup trucks
HDV: Heavy-duty vehicles
MC: Motorcycles
OFF: Off-road equipment
R: Research
MO: Monitoring of fleet emissions
H: Identification of individual high emitters for inspections or tampering
L: Identification of individual low emitters for a "clean screen" program
MS: Identifying groups of high emitting vehicles for market surveillance

Source: ICCT 2019, Worldwide use of remote sensing to measure motor vehicle emissions

The equipment for testing is mobile – can be moved from place to place as the need arises. It would be best if the testing is done on elevated areas, like flyovers as this is where the pollution is the highest. EPCA suggests that the first testing sites should be close to the major entry points (toll gates) into Delhi so as to identify gross polluters from heavy vehicles.

Figure 3a: Schematic setup of a plume chaser installed in vehicle measuring the exhaust emissions from the truck in front   **Figure 3b:** Schematic setup of a stationary air sampling system.

Source: ICCT 2019, Worldwide use of remote sensing to measure motor vehicle emissions

The following needs to be done in order to implement the plan. This plan is based on the report of ICAT, which was submitted to the Hon'ble Court at its directions.

Plan for implementation of use of Remote Sensing technology for monitoring vehicle emissions with suggested agencies and time-lines

Sno	Recommended action	Agency	Deadline
1	Frame rules under CMVR for use of remote sensing for PUC, including penalties so that enforcement is possible	MoRTH	3 months
2	Notify the gross polluter threshold under CMVR as recommended by ICAT	MoRTH	3 months
3	Issue technical guidance on design of programme, including equipment, networking and data sharing	MoRTH	2 months
4	Global tender for purchase of 5 machines and its operation	Delhi Transport Department	3 months
5	Finalisation of site and sampling plan	Delhi Transport Department	3 months

Annexure I
Technical note on steps to be taken for implementation of remote sensing programme for monitoring vehicle emissions

1. Choice of remote sensing equipment

Selection of remote sensing devices: The schematic of a cross-road setup of units of the remote sensing device for both cross-road and top-down remote sensing systems explain the different approaches (Figure 1)[4]. The setup consists of a light source with the reflecting strip/mirror and the light detector, the speed and acceleration detectors, the plate number recorder, and a weather sensor. The data processing system consists of telemetry equipment, display equipment, data server, video data server, backup server, router, network printer, mobile workstation, firewall, etc.

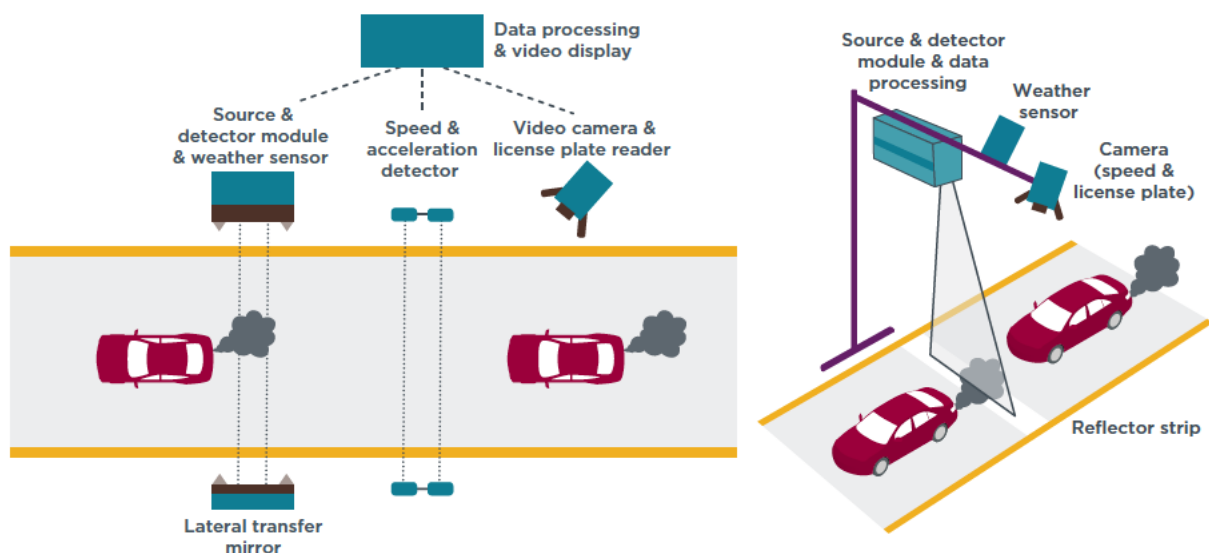**Figure 1: Approaches to remote sensing measurements**

Figure 1: Remote sensing setup

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[4] https://theicct.org/publications/worldwide-use-remote-sensing-measure-motor-vehicle-emissions
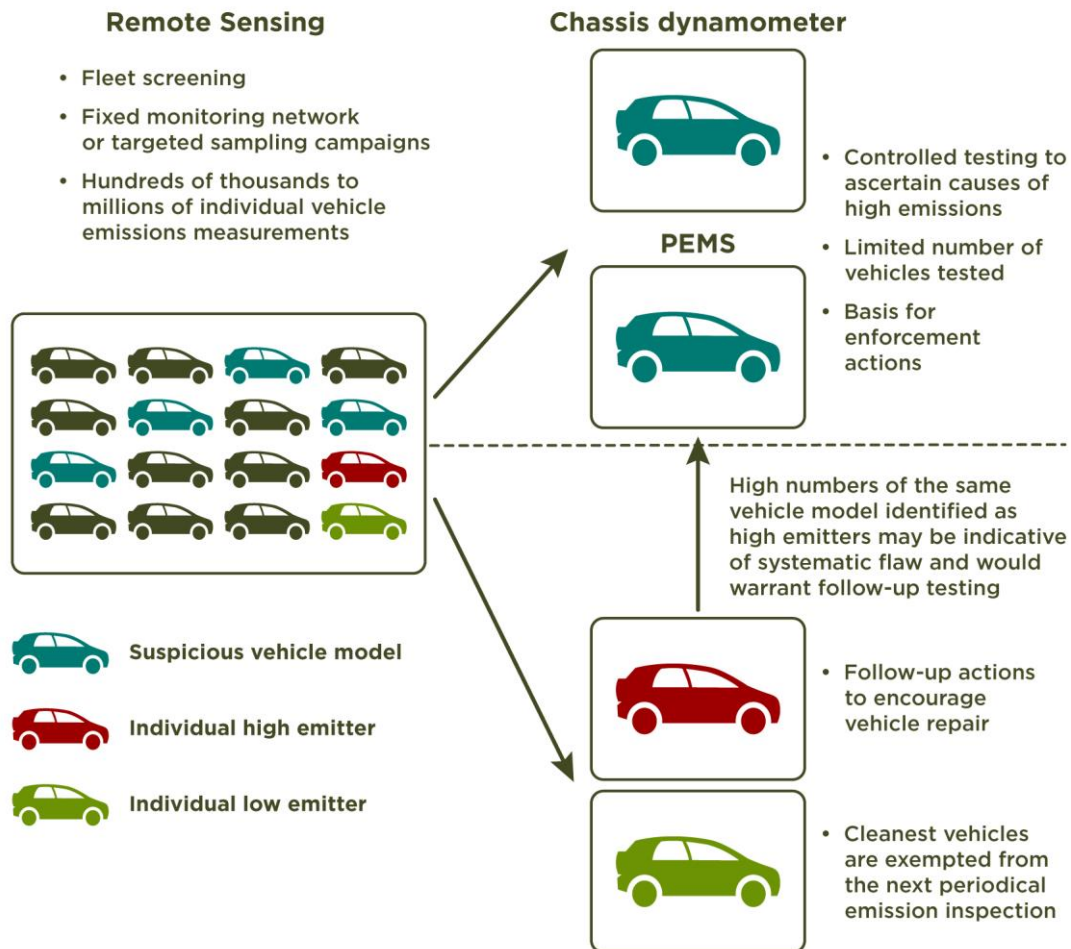
Figure 1: Possible applications of vehicle remote sensing in an enhanced vehicle emissions control program.

2. Pollutants to be measured

The system should be capable of measuring NO, NO_2, HC, CO, CO_2, and opacity at a minimum. Measurement of N_2O, NH_3, SO_2, and CH_4 is desired, but not necessary.

A complete remote sensing record for an individual vehicle should contain the following information:

- the concentration measurement of each emission above the concentration in ambient air;
- the vehicle's speed and acceleration;
- the measurement conditions: road grade, ambient temperature and pressure, and relative humidity;
- the vehicle's technical information, including brand, model, category, model year, body type and size, fuel type, engine size, emission standard, type-approval CO_2 value where available, and empty vehicle mass.

3. Key manufacturers of remote sensing equipment and expected cost of equipment

At least half a dozen manufacturers of remote sensing equipment exist globally as shown in Table below.[5] Chinese companies are also manufacturing this equipment.

Table 1: Main remote sensing technologies and manufacturers.

Type	Position	Provider / Inventor	Equipment name	Measurement	Measures
Open path	Cross-road	University of Denver	FEAT	Arc lamp light beam with mirror reflector	CO, HC, CO_2, NO, NO_2, NH_3, SO_2, opacity
	Cross-road	Opus	RSD 4600 and older	Arc lamp light beam with mirror reflector	CO, HC, CO_2, NO, opacity
			RSD 5000		CO, HC, CO_2, NO, NO_2, NH_3, opacity
	Cross-road	Environmental Technology Consultants	R-series S650	Arc lamp light beam with mirror reflector	CO, CO_2, HC, NO, NO_2
	Cross-road; Overhead	Dopler Eco Technologies	DPL7000 Series	Laser light beam with mirror reflector	CO, CO_2, HC, NO, opacity
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	Plume chaser	University of Birmingham	SNIFFER	Exhaust plume sample	NO, NO_2, CO_2
	Plume chaser	CARB	Mobile Measurement Platform (MMP)	Exhaust plume sample	CO, CO_2, HC, NO_x, PM, PN, Black Carbon

4. Site selection

Vehicle emissions are dependent on driving conditions (speed, acceleration, gradient of the road, time since the engine was started, traffic, etc.). Therefore, the selection of sites for remote sensing should take into account variability of driving conditions, while ensuring that measurement of emissions can take place accurately[6]. Key considerations for site selection include:

- Single lane roads to prevent interference from nontarget vehicle exhaust plumes

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[5] Ibid
[6] https://theicct.org/publications/true-london-dec2018

- Steady traffic flow to provide sufficient sampling rates and to avoid sampling disruptions during periods of congestion
- Slight upward slope or locations where vehicles are under acceleration in order to provide engine load
- Sufficient distance from residential areas to limit measurements of cold engines
- Adequate space to set up instrumentation and ensure operator safety without disrupting traffic flows

5. Number of remote sensing set ups required

Vehicle emissions are currently being monitored in Hong Kong with the help of 14 sets of equipment, which are rotated around between 158 sites[7]. Each city in Jing-Jin-Ji area of China is required to install at least 10 stationary and 2 mobile sets of remote sensing equipment[8]. The NCT may therefore require between 12-15 setups to adequately cover the entire area. At least five setups should be procured initially, with the rest added after gaining experience with the initial setups for one year. A detailed sampling plan should be developed to include a number of sites around the NCT that meet the site selection criteria.

6. Data management

All data from the remote sensing measurements should be stored in centralized database owned by Delhi Transport Department. A version of the emissions data without the license plate and vehicle owner details, but identifying the make, model, and year of vehicle should be released to the public so that researchers may be analyze the data for trends in vehicle emissions, and/or identify systemic problems with vehicles of certain make or type.

7. Identification of individual high emitters

As suggested in ICAT report, the first phase of the program should focus on identifying the gross polluters, with a particular emphasis on heavy-duty vehicles. This can be done by setting a single pollutant-specific cut point per fuel-type, technology group, and Bharat emission norms. The threshold should be lowered every two to three years to go after other high emitters. All vehicles identified as high emitters should be sent a letter warning the vehicle owner to immediately repair their vehicle, and/or pass a confirmatory test at I/M facility. The confirmatory test should be a loaded

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[7] https://www.ncbi.nlm.nih.gov/pubmed/29482019
[8] 2017 Jing-jin-ji Air Pollution Prevention and Control Plan

mode test to ascertain that repairs have been carried out, and that the vehicles are no longer gross polluters. In absence of a test certificate obtained within 30 days, the insurance and/or registration of vehicles should be cancelled. Delhi traffic police would be responsible for enforcement of this provision in NCT. Delhi government may also double the ECC for vehicles found as gross polluters.

According to the Chinese remote sensing standard, a vehicle is considered as a non-compliant if it exceeds the limits for the same pollutant in two or more consecutive remote sensing tests in 6 months. Adopting a similar approach, insurance certificate for a vehicle which is found to fail twice in remote sensing measurements should be voided with immediate consequence, and a fiscal penalty be assessed.