



# Technical Assistance Consultant's Report

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Prepared by: Kim Jong Choon  
Seoul, Republic of Korea

For: South Asia Department  
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# Motor Vehicles Emission and Approval System in Bhutan

TA-8572(REG) Action on Climate Change in South Asia



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**Author:** Jong Choon Kim, Ph. D

**Contact Details:** Seoul, Republic of Korea

(Email) [kjc55@hanmail.net](mailto:kjc55@hanmail.net), (C/P) +82(0)10-8780-0768

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## Acronyms

ASM	Acceleration Simulation Mode
BPM	Back and Pressure Modulated
CO <sub>2</sub>	Carbon Dioxide
COC	Certificate of Conformity
CVS	Constant Volume Sample
DOC	Diesel Oxidation Converter
EECS	Exhaust Emission Control Standards
EGR	Exhaust Gas Recirculation
Hb	Hemoglobin
HC	Hydrocarbon
LPG	Liquefied Petroleum Gas
MOT	Ministry Of Transportation
NDIR	Nondispersive Infrared sensor
NEC	National Environment Commission
NGO	Non Government Organization
PAH	Polynuclear Aromatic Hydrocarbon
PAN	Peroxyacetyl Nitrate
PM	Particulate Matter
R&D	Research and Development
RSTA	Road Safety and Transport Authority
SOF	Soluble Organic Fraction
VIMS	Vehicle Inspection Management System
VIN	Vehicle Identification Number
VM	Vacuum Modulated
VOC	Volatile Organic Compound
VVM	Venturi Vacuum Modulated

## Summary

### 1. Objectives

Vehicles Emission and Approval System means that management systems are controlled by checking the information/technical documents and also by performing the tests/inspections for vehicles so that the authorized Government department can certify whether the exhaust gases and noises emitted from vehicles are conformed with the relevant regulations stipulated by Government or not, prior to manufacturing and selling of motor vehicles.

### 2. Legal Requirements and Responsibilities of Governments

The responsible Government department of Bhutan shall stipulate all regulations with regard to motor vehicle emission and approval system and also enforce the regulations strictly for new imported vehicles and in-use vehicles in order to save and protect air quality.

### 3. Types of Approval (Certification) <sup>1</sup>

- (1) New Approval: For vehicle's family that have similar characteristics with regard to vehicle emission and noise (same family vehicles).
- (2) Extension Approval: For vehicles that have been changed with regard to emission system and its technical structures from already approved vehicles.
- (3) Omit of Approval: For small series vehicles having with below purposes
  - For national team and its training that confirmed by Sports Minister
  - For donated to Government organization or NGO from overseas, free of charge
  - For citizen who had lived more than 1 year overseas will take only 1 vehicle as a moving goods
  - For diplomat or foreign country soldier's family to be imported
  - For ground working of Airplane
  - For vehicles that Minister of Environment recognize to need omit of approval
- (4) Exemption of Approval: For vehicles having with below special purposes
  - For special purposes such as army and nation guard and fire extinguishing
  - For foreign country soldier who willing to use for public
  - For exporting or exhibition display that will be returned to foreign country soon
  - For traveler in conditions that will be returned to foreign country soon
  - For development or R&D, imported vehicles from foreign country by vehicle manufacturers or R&D laboratories
  - For zero emission vehicles such as electric, sun light, hydrogen vehicles

### 4. Proposal for motor vehicles emission and approval system in Bhutan

(1) First of all, the authorized government organization shall stipulate regulations for motor vehicles emission and approval system.

(2) After legislation, the authorized government organization also shall organize infra systems in order to implement the regulations strictly. Thus, Bhutan Government make peoples follow and obey the regulations to improve their health and living qualities.

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<sup>1</sup> Report: Understanding of Vehicle emission Type approval by Korea TPRC (1) (Transportation Pollution Research Center)

(3) If the vehicle owners who are still driving the vehicles that have not satisfied in-use vehicle's limits, due to no repairs or maintenances, are detected by responsible officers, the control officers shall give high fine/penalty ticket to drivers and shall order to not drive the troubled vehicles any more so that the drivers can repair the vehicles and meet the limits.

(4) The Bhutan Government shall install (build) the nationwide electronic VIMS<sup>2</sup> (Vehicle Inspection Management System) so that they can 1) perform the emission inspection for in-use vehicles efficiently and can 2) standardize of inspection works and can 3) operate vehicle inspection management system stably such as inspection data's automatic transmission, after test center have inspected for in-use vehicles.

(5) Bhutan Government shall development the inspection and repair training program that are required for emission inspection for in use vehicles.

(6) Also Bhutan Government shall grant Certificate to certified inspector and repair technician who have passed the qualification requirements.

I have proposed the detailed motor vehicles emission and approval system in No 13.  
(Proposals for Vehicle Emission and Approval System in Bhutan)

I hope really these proposals are very helpful to responsible Government organization who are willing to make a relevant regulations and implement the regulations efficiently.

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<sup>2</sup> 2016 Korea Vehicle Inspection Statistics by Korea Transportation Safety Authority

## 1. Introduction

### 1.1. Report Objective and Overview

This report is for Bhutan Government to introduce and implement Motor vehicles emission and approval system in order to control the emission pollutants from the new imported vehicles and in-use vehicles.

With regard to trend of increase in the number of automobiles, we can expect the number of automobiles has steadily increased from now on in Bhutan.

The sharp increase in the number of automobiles makes the people's living patterns to be comfort and fast. However, the side effects, such as the atmospheric pollutions on the public, occur. Due to the increase in the exhaust emission from the automobiles, the big cities, such as capital, have exceeded the standards of the atmospheric pollution. In addition, the level of ozone warnings is increasing.

In order to keep sound environmental conditions and reduce the atmospheric pollutions, proper measures via the analysis of the air pollutants should be taken.

The extents of pollution depend on the types of vehicles, fuels, the vehicle conditions, such as the driving mileage, the maintenance conditions and the driving conditions.

In general, CO and HC are the dominant air pollutants of gasoline- and LPG-fueled vehicles, and NOx and PM are the dominant pollutants of diesel-fueled vehicles.

### 1.2. The frame work of this report

This report provide:

- a) How to control the new imported vehicles and in-use vehicles by Bhutan Government, such as emission limits, approval procedures, test method, required document form.
- b) In order to understand the vehicles emission and approval system, the important and essential knowledges are explained easily to understand.
- c) The electronic network systems (VIMS: Vehicle Inspection Management System) with data automatic transmission for emission data and vehicles information (Vehicle Name, Registration No, VIN No, Model Year, Category, Owner name, CC, etc.), after test centers have inspected for in-use vehicles.

To avoid the difficulty and burden to Bhutan Government, I recommend the Bhutan Government to install the gradually nationwide network systems of two stages as below:

- 1<sup>st</sup> Stage and
- 2<sup>nd</sup> Stage

☞ For details: See No. 12 (Proposals for Vehicle Emission and Approval System)

## 2. Classification of Power-Driven Vehicles and Trailers<sup>3</sup> for Bhutan

### 2.1. Category L – Motor Vehicles with Less than Four Wheels

### 2.2. Category M – Power-Driven Vehicles Having at least Four Wheels and Used for the Carriage of Passengers

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<sup>3</sup> See ECE R.E.3. Para. 2



(1) Category M1: Vehicle used for the carriage of passengers and comprising not more than 8 seats in addition to the driver's seat.

(2) Category M2: Vehicle used for the carriage of passengers and comprising more than 8 seats in addition to the driver's seat, and having a maximum mass not exceeding 5t.

(3) Category M3: Vehicle used for the carriage of passengers and comprising more than 8 seats in addition to the driver's seat, and having a maximum mass exceeding 5t.

(4) Vehicles of Category M2 and M3 belong to:

- For vehicles > 23 persons including driver, there are three classes of vehicles:

“Class I”: Vehicles constructed with areas for standing passengers, to allow frequent passenger movement.

“Class II”: Vehicles constructed principally for the carriage of seated passengers, and designed to allow the carriage of standing passengers in the gangway and/or in an area which does not exceed the space provided for two double seats.

“Class III”: Vehicles constructed exclusively for the carriage of seated passengers.

- For vehicles ≤ 23 persons including driver, there are two classes of vehicles:

“Class A”: Vehicles designed to carry standing passengers; a vehicle of this class has seats and shall have provisions for standing passengers.

“Class B”: Vehicles not designed to carry standing passengers; a vehicle of this class has no provisions for standing passengers

(5) Mass of a vehicle in running order: the mass of an unladen vehicle with bodywork, and with coupling device in the case of a towing vehicle, or the mass of the chassis with cab if the manufacturer does not fit the body work and/or coupling device, including coolant, oils, 90% of fuel, 100% of other liquids except used waters, tools, spare wheels, driver (75kg) and, for buses and coaches, the mass of the crew member (75kg) if there is a crew seat in the vehicle.

### 2.3. **Category N** – Power-Driven Vehicles Having at Least Four Wheels and Used for the Carriage of Goods

(1) Category N1: Vehicle used for the carriage of goods and having a maximum mass not exceeding 3.5t.

(2) Category N2: Vehicle used for the carriage of goods and having a maximum mass exceeding 3.5t but not exceeding 12t.

(3) Category N3: Vehicle used for the carriage of goods and having a maximum mass exceeding 12t.

### 2.4. **Category O** – Trailers (Including Semi-Trailers)

(1) Category O1: Trailers with a maximum mass not exceeding 0.75t.

(2) Category O2: Trailers with a maximum mass exceeding 0.75t, but not exceeding 3.5t.

(3) Category O3: Trailers with a maximum mass exceeding 3.5t, but not exceeding 10t.

(3) Category O4: Trailers with a maximum mass exceeding 10t.

**2.5. Special purpose vehicles** - A vehicle of Category M, N or O for conveying passengers or goods and for performing a special function for which special body arrangements and/or equipment are necessary.

- (1) Motor caravan: A special purpose M1 Category vehicle constructed to include accommodation space which contains at least the following equipment:
  - (a) Seats and table
  - (b) Sleeping accommodation which may be converted from the seats
  - (c) Cooking facilities, and
  - (d) Storage facilities
- (2) Armoured vehicle: Vehicle intended for the protection of conveyed passengers and/or goods and complying with armour plating anti-bullet requirements.
- (3) Ambulance: Motor vehicle of Category M intended for the transport of sick or injured people and having special equipment for such purpose.
- (4) Hearse: Motor vehicle intended for the transport of deceased people and having special equipment for such purpose.

### 3. Diesel Vehicles <sup>4</sup>

3.1. Definition: Vehicles is using the diesel fuel as a power-driven sources with compression ignition engine.

3.2. Difference between Petrol and Diesel Vehicles

Contents	Petrol Vehicles	Diesel Vehicles
Fuel	Petrol, LPG	Diesel
Combustion System	Mix of fuel and air→ to cylinder →compression and forced firing & exploding by ignition plug	Only air→ to cylinder→ compression of air→ injection of diesel→ auto-firing & exploding by auto-ignition
Fuel Supplying System	Carburetor or Electric Control Injection	Mechanical or Electric Control Injection
Combustion Characteristic	Mixed gas with 0.8~1.5 excess of air ratio ( $\lambda$ : air-fuel ratio ÷ theoretical air-fuel ratio) burned by electric spark	By difficulty of equal mixture due to injection of diesel to compressed air, $\lambda$ is not constant. Thus, it is burned in conditions of sufficient air
Exhaust Emission Gas Characteristic	Mainly emit CO, HC, NO <sub>x</sub> and HC is emitted by evaporative and blow-by gas	NO <sub>x</sub> , Smoke, PM are emitted more high than Petrol, but CO, HC is less than Petrol
Noise & Vibration	Noise & Vibration are less than Petrol due to compression ratio is low(8~9)	Noise & Vibration are more high than Petrol due to compression ratio is high(15~20)
Fuel Consumption	Fuel is consumed high due to combustion efficiency is low	Fuel is consumed low due to combustion efficiency is high. Especially, in heavy traffic jam conditions

### 3.3. Exhaust Gas Allowable Limits

- (1) The Exhaust Gas Allowable Limits shall be gradually strengthened by long-term plan so that Bhutan can save air quality and improve people health.

<sup>4</sup> Report: Status and Control Strategy of the Pollutions by Automobiles in Korea 2006

a) Diesel Light-Duty Vehicles

Country	Application year	Emission toleration standard (g/km)				Test method
		CO	THC	NOx	PM	
Korea	1996	6.21	0.5	1.43	0.31	CVS-75 mode
	1998	2.11	0.25	1.4	0.25	
	2000			1.06	0.14	
	2004			0.71	0.08	
EU	1998	—	—	1.2	0.17	ECE15+EUDC
	2000	—	—	0.87	0.07	

b) Diesel Heavy-Duty Vehicles

Country	Application year	Emission standard (g/kwh)				Test method
		Truck		Bus		
		NOx	PM	NOx	PM	
Korea	1996	11.0	0.9	11.0	0.9	D-13
	1998	6.0	0.25	9.0	0.5	
	2000	6.0*(7.0)	0.2(0.15)	6.0(7.0)	0.2(0.15)	
	2002	6.0	0.15	6.0	0.1	
EU	1996(EURO2)	7.0	0.15	7.0	0.15	ECE13
	2000(EURO3)	5.0	0.1	5.0	0.1	
	2005(EURO4)	3.5	0.1	3.5	0.1	

\* Limits of ( ) shall apply to Turbo.

### 3.4. Reduction Technologies of Vehicles Exhaust Gas

#### (1) Overview of Reduction Technologies of Vehicles Exhaust Gas

Improve Fuel	Improve Engine	After Treatment Technology
<ul style="list-style-type: none"> <li>- Improve Diesel Fuel                             <ul style="list-style-type: none"> <li>● Content of Sulphur: <math>\leq 0.05\%</math></li> </ul> </li> <li>- Alternative Fuel                             <ul style="list-style-type: none"> <li>● CNG</li> <li>● Methanol</li> <li>● CNG + Diesel</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>- Improve Combustion chamber (Reentrant, Toroidal)</li> <li>- Improve Fuel System                             <ul style="list-style-type: none"> <li>● High Pressure Injection (Tag, Common Rail)</li> <li>● Electric Control of Fuel Injection Quantity &amp; Timing</li> </ul> </li> <li>- Turbo-Intercooler, VGT</li> <li>- Cooled-EGR</li> </ul>	<ul style="list-style-type: none"> <li>- DPF</li> <li>- DOC</li> <li>- De-NOx Catalyst,</li> <li>- SCR Catalyst</li> </ul>

#### (2) Technologies applied to Diesel Vehicles

##### a) EGR Technology

1) Overview of technology: Exhaust Gas Recirculation is to recirculate the parts of exhaust gas to intake system. EGR can grow concentration of CO<sub>2</sub> and reduce NO<sub>x</sub> due to low temperature in combustion.

##### 2) Type of EGR

According to control type of flow rate, EGR can be classified as below.

- VM (Vacuum Modulated) EGR
- BPM (Back Pressure Modulated) EGR
- BPM & VVM (Back Pressure & Venturi Vacuum Modulated) EGR

Low pressure route installed with EGR channel from turbine exit of turbo charger to entrance of compressor is able to control the quantity of EGR in wide working range of engine due to high difference of pressures. But, the compressor and inter-cooler's durability and reliability will be troubled and intake temperature may exceed design temperature of compressor due to exhaust gas pass through the compressor and inter-cooler.

On the other hand, high pressure route connected with EGR channel from exhaust manifold before entrance of turbine to intake manifold after compressor do not affect the compressor and inter-cooler's durability and reliability due to exhaust gas do not pass through the compressor and inter-cooler.

##### 3) Trend of technology developments

Up to this time, the mechanical type of EGR has been used mainly. But, the electronic control type of EGR will be used in the future because EGR requires more detailed control and fast working in order to meet gradually strict emission limits.

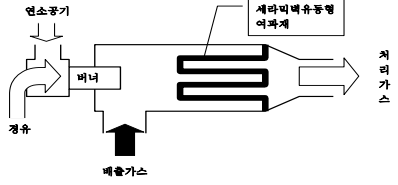
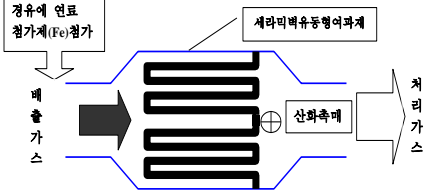
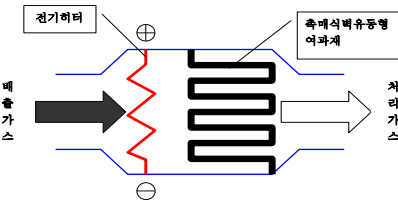
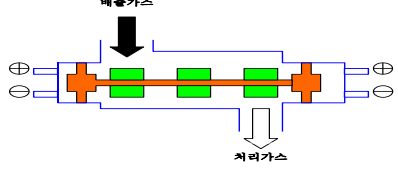
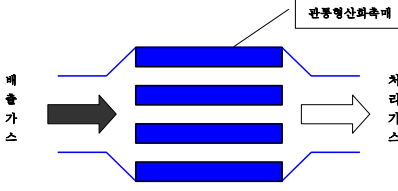
##### b) After treatment Technology

DPF (Diesel Particulate Filter Trap) is device that can be able to reduce the maximum 70% of PM (Particulate Material) from diesel engine by filter collecting of PM, by burning of collected PM continuously.

DPF has a very excellent performance of PM reduction, but is expensive and durability is not good.

DPF technology consist of trapping and regeneration for PM and its system have 3 parts: filter, regeneration unit, control unit.

**Comparison Table of most popular DPF and DOC (Diesel Oxidation Converter)**

Regeneration Type	Device drawing	Advantage	Dis-Advantage
Diesel burner		<ul style="list-style-type: none"> <li>•Adapting to Large engine easily</li> <li>•Easy regeneration</li> </ul>	<ul style="list-style-type: none"> <li>• High fuel consumption</li> <li>•Not easy to install (Mounting Space)</li> </ul>
Additive		<ul style="list-style-type: none"> <li>•Devices is simple</li> </ul>	<ul style="list-style-type: none"> <li>• High fuel consumption</li> <li>•Not easy to install (Mounting Space)</li> <li>•Rising of 2<sup>nd</sup> pollution</li> </ul>
Converter		<ul style="list-style-type: none"> <li>•Low electric consumption</li> <li>•Protection of filter breakage from thermal shock</li> </ul>	<ul style="list-style-type: none"> <li>• Output of Sulfate fuel consumption</li> <li>•Rising of 2<sup>nd</sup> pollution</li> </ul>
Plasma		<ul style="list-style-type: none"> <li>•Simple inside system</li> <li>•Reduction of NOx, PM at the same time</li> </ul>	<ul style="list-style-type: none"> <li>• High fuel consumption</li> <li>•Not easy to install (Mounting Space)</li> </ul>
DOC		<ul style="list-style-type: none"> <li>•Good to control gaseous CO, HC</li> <li>•Easy regeneration</li> </ul>	<ul style="list-style-type: none"> <li>• High fuel consumption</li> <li>•Not easy to install (Mounting Space)</li> </ul>

#### 4. Petrol Vehicles <sup>5</sup>

4.1 Definition: Vehicles is using the petrol fuel as a power-driven sources with injection and ignition engine. After mixed the ration of air and fuel as a 14.7:1, send and compress the mixed air/fuel in combustion chamber up to high temperature/high pressures and explode it by electric ignition and gain the driven powers.

<sup>5</sup> Report: Status and Control Strategy of the Pollutions by Automobiles in Korea 2006

#### 4.2. The sources of exhaust emission:

Exhaust gas, blow-by gas, evaporation gas depending on generating sources.

##### (1) Exhaust gas

This gas is burned gas emitted from exhaust pipe and mainly consist of NO<sub>x</sub> (71%), Carbon dioxide (CO<sub>2</sub>, 18.1%), Water vapor (9.2%) at conditions of medium load and medium speed of engine. The air pollutant of exhaust gas are below.

- CO
- HC
- NO<sub>x</sub>

##### (2) Blow-by gas

This gas is emitted from valve working chamber or head cap, after flowing to crankcase throughout of gap between piston and cylinder. The most of passenger vehicles will burn again blow-by gas recirculate it to air intake system. It consist of HC burned not perfectly.

##### (3) Evaporation gas

It is evaporated from vaporizer system or cap of fuel tank and is emitted to air. It consist of HC.

#### 4.3. Technologies applied to Petrol Vehicles

##### (1) 3 way catalytic converter

This consist of substrate packaged inside of steel can and wash-coat on the upper of substrate and thin layer of catalytic material sprayed on wash-coat.

I) Types of substrate are as below.

- 1) Ceramic substrate
- 2) Ceramic honeycomb type
- 3) Metallic wire substrate
- 4) Wash-coat and coating layer: Pt, Rh, Pd.

##### II) Operation condition of catalytic converter

The air fuel ratio control that use catalytic converter is the most effective method to reduce the exhaust emission from petrol engines until now. The catalytic converter is able to reduce NO<sub>x</sub>, HC, CO.

The oxidation catalytic converter, reduction catalytic converter and 3-way catalytic converter are very useful.

If 3 way catalytic converter is operated in small area ( $\leq 1\%$ ) nearby  $\lambda=1$ (theoretical excess air ratio), it is able to reduce maximum 90% of air pollutant CO, HC, NO<sub>x</sub>.

##### (2) EGR (Exhaust Gas Recirculation)

It recirculates the some parts of exhaust gas (up to 15% of mixed air) from exhaust route to intake air route and burn it gain. The recirculated exhaust gas will lower the combustion temperature. If the combustion temperature is getting lower, maximum 60% of NO<sub>x</sub> will be reduced.

But, HC and CO are not reduced by EGR.

#### 4.4. Exhaust emission reduction rate: Before and after of repairs and maintenance for in use vehicles

In order to study the relation with repairs/maintenance and emission related components, I have tested by CVS-75 mode the vehicles that cannot meet approval limits, after general repairs of changing filters, oil and changing O<sub>2</sub> sensor, catalytic converter in sequence.

The test results are as below.

**Test results after general repairs of changing filters, oils**

Pollutant	Before repairs(g/km)	After repairs(g/km)	Reduction rate (%)
HC	0.47	0.42	10.6
CO	3.86	3.46	10.4
NOx	0.40	0.44	-10.0
Total	4.73	4.32	8.7

**Test results after repairs of changing O2 sensor**

Pollutant	Before repairs(g/km)	After repairs(g/km)	Reduction rate (%)
HC	0.47	0.31	16.2
CO	5.02	3.41	32.1
NOx	0.79	0.67	15.2
Total	6.18	4.39	29.0

**Test results after repairs of changing 3 way catalytic converter**

Pollutant	Before repairs(g/km)	After repairs(g/km)	Reduction rate (%)
HC	0.40	0.16	60.0
CO	4.35	1.11	74.5
NOx	0.56	0.18	67.9
Total	5.31	1.45	72.7

As you can see above, the 3 way catalytic converter is most effective method to reduce pollutants because it can reduce maximum 60 % of pollutant after changing it.

## 5. The Automobile Pollutants <sup>6</sup>

### - Photochemical smog and ozone (O<sub>3</sub>)

Photochemical smog is the phenomenon of the environmental pollution, resulted from peroxide, such as O<sub>3</sub>, aldehyde and PAN (Peroxyacetyl Nitrate) formed by the photochemical reactions between NO<sub>x</sub> and VOC (Volatile Organic Compound) with the sunlight.

The higher the ozone concentration formed by photochemical smog is, the more the eyes are irritating, and the heavier the chest feels and the more a headache increases. It leads to increase in cold patients and respiratory ailments such as asthma. It does damage to crops and synthetic rubber, and reduces the sight distance by sulphate, nitrate and organic acid formed through the chemical reaction with sulfurous acid gas, nitrogen oxides and hydrocarbon in the air.

### - Particulate Matter (PM)

PM is the carbon elements mainly exhausted from diesel-fueled vehicles. It also includes SOF (Soluble Organic Fraction) and is very minute particles as big as 0.1 ~ 0.3 $\mu$ m. Therefore, it is deposited to an alveolus through breathing, and leads to the inflammation of a mucous membrane and decrease in the function of the lung. Obviously, it can increase the possibility of respiratory diseases.

<sup>6</sup> Report: Understanding of Vehicle emission Type approval by Korea TPRC (2) (Transportation Pollution Research Center)

- **Carbon monoxide (CO)**

CO is formed by the imperfect combustion, and is the most dominant out of any other pollutants and colorless, odorless and tasteless. It is easily combined with Hb (Hemoglobin), which leads to the damage of the body by reducing the ability of the oxygen supply to an organization.

Even at low concentration of CO-Hb in the blood, it leads to the decrease in the ability of intelligence, the reflex and to the angina. Also, it has an effect on the growth rate of an unborn child and the organization development of a child. At a high rate, it leads to a headache, dizziness, the paralysis of hands and feet, the decrease in judgement and ultimately to the death.

- **Hydrocarbons (HCs)**

HCs are formed by various reactions from the low molecular HCs to the particulate materials, such as PAH (polynuclear aromatic hydrocarbon) of benzopyrene.

HCs contain olefin HCs of active photochemical reactions and harmful aromatic HCs. The concentrations of HC in the air are very low. It gives an indirect damage, but creates Ozones via the chemical reaction with nitrogen oxide, which leads to the atmospheric pollution and do the harm to the human body.

- **Nitrogen oxide (NO<sub>x</sub>)**

NO<sub>x</sub> is formed by the chemical reaction of nitrogen and oxygen during the combustion in the high temperature, and consists of NO and NO<sub>2</sub>. NO is changed to NO<sub>2</sub> via oxidization in the air. Thus, most exhausted from the engine is NO<sub>2</sub>. In general, NO<sub>x</sub> represents NO and NO<sub>2</sub>.

NO<sub>2</sub> causes the edema of the lungs, bronchitis and pneumonia.

## 6. The Control Strategy of the Automobile Pollution in Korea

### 6.1. The stringent limits of exhaust emission for the manufactured vehicles

1) Limits of exhaust emission(EU and Korea) for Gasoline passenger vehicles is shown in Table 1.

**Table 1. Exhaust emission limits of gasoline passenger vehicles**

Country	pollutant	unit	1970	1973	1975	1978	1980	1981	1986	1987	1994	2000	2003	2004	2006
K O R E A	CO	g/km	-	-	-	-	26.0	←	←	2.11 <sup>1)</sup>	←	2.11/ 2.61 <sup>3)</sup>	←	←	1.06
	HC	g/km	-	-	-	-	3.8	←	←	0.25 <sup>1)</sup>	←	0.16/ 0.19 <sup>3)</sup>	0.047/ 0.056 <sup>4)</sup>	←	0.025
	NO <sub>x</sub>	g/km	-	-	-	-	3.0	←	←	0.62 <sup>1)</sup>	←	0.25/ 0.37 <sup>3)</sup>	0.12/ 0.19 <sup>4)</sup>	←	0.031
E U	CO	g/km	-	-	Remark 6)					2.3 <sup>7)</sup>	2.2 <sup>8)</sup>	2.3	←	1.0 <sup>9)</sup>	←
	HC	g/km	-	-						0.97 <sup>7)</sup>	0.5 <sup>8)</sup>	0.20	←	0.10 <sup>9)</sup>	←
	NO <sub>x</sub>	g/km	-	-								0.15	←	0.08 <sup>9)</sup>	←

Remarks:

1. The first certification vehicles are applied after 1987. 7 and vehicles on manufacturing are applied after 1998. The test method changed to CVS-75 mode from 10 method of Japan

2. The test methods were changed to 10.15 mode from 10 method.

The values of mean values.

3. The emission warranty period regulation of 5years/80,000km or 10years/160,000km



4. Gradually applied from 2003 to 2006(25%, 50%, 75% and 100%)
5. Gradually applied from 2003 to 2006(Bin# 1 ~ 10).
- The values are Bin#5.and HC until 2000's Standard (EURO3)
6. Applied in 1992, 8. Applied in 1996, 9. Applied in 2005

## 2) Diesel heavy duty vehicles

Diesel heavy duty vehicles have advantages, such as big displacement and long driving mileage. The pollution emission contribution to the total air pollution is very high. The developed countries, such as USA, have been decreasing exhaust emissions by tightening the regulation from the 1990's. Each country's exhaust emission limits of diesel heavy duty vehicle is shown in Table 2.

**Table 2. Exhaust emission limits of diesel heavy duty vehicle**

country	pollutant	unit	1984	1988	1990	1991	1993	1994	1995	1996	1998	2000	2001	2004	2007
K O R E A	CO	g/kwh	980 ppm	←	←	←	←	←	←	4.9	←	←	3.0	2.1	1.50
	HC	g/kwh	670 ppm	←	←	←	←	←	←	1.2	←	←	1.0	0.66	0.46
	NOx	g/kwh	1000 ppm	850 ppm	←	←	750 ppm	←	←	11.0	6.0 (9.0)	6.0	6.0	5.0	3.50
	PM	g/kwh	-	-	-	-	-	-	-	0.9	0.25 (0.5)	0.25 (0.1)	0.2	0.10	0.02
EU	CO	g/kwh		14.0	11.2	←	4.5	←	4.0	←	←	2.80	←	1.5 <sup>4)</sup>	←
	HC	g/kwh		3.5	2.4	←	1.1	←	1.1	←	←	0.70	←	0.46 <sup>4)</sup>	←
	NOx	g/kwh		18.0	14.4	←	8.0	←	7.0	←	←	5.0	←	3.5 <sup>4)</sup>	2.0 <sup>5)</sup>
	PM	g/kwh		-	-	-	0.36	←	0.15	←	←	0.10	←	0.02 <sup>4)</sup>	←
I N D I A  (Including of Light duty, PC Vehicles)	Indian test cycle : max speed is 90km/h compared to 120 km/h for the NEDC														
	Bharat Stage IV-Euro 4		From Apr 2010					National Capital Region (Dehli), 13 cities							
			From Jul 2015					Above + plus 29 cities							
			From Oct 2015					North India + bordering districts of Rajasthan (9 States)							
Indonesia			From Apr 2016					Western India plus + South and East India (10 States and Territories)							
			From Apr 2017					Nationwide							
	Bharat Stage V-Euro 5		From Apr 2019 for new models, Apr 2020 for existing models					Nationwide							
	Bharat Stage VI-Euro 6		From Apr 2021 for new models, Apr 2022 for existing models					Nationwide							
	Euro 2		New Models					Jan 2005							
			Existing Models					Jan 2007							
Philippines	Administrative Order No.2010-23 also states that starting in Jan 2016, all new passengers cars and LD vehicles will be required to meet Euro 4 emission standards, subject to 50 ppm sulfur fuel availability														
Thailand	Euro 4			Since Jan 2012											
	Euro 4			From Jan 2013											

<sup>7</sup> Worldwide Emission Standards by Delphi

1. Values in ( ) are the city bus regulation, values of Japan in ( ) are average.

2. Applied in 1997, 3. Applied in 2003, 4. Applied in Oct. 2005.

5. Applied in Oct. 2008, 6. Applied in 2005.

Since the regulation of the exhaust emission of diesel-fueled vehicles in Korea was started in July, 1984, the regulation standard has changed from the mass basis to the concentration basis and become as severe as the regulation of EU of 2002.

EU regulated PM in 1993, adopted the regulation of USA's 1995 in 1995 and tightened the regulation in 2000 as severe as that of USA of 1998.

## 7. Emission warranty period of Vehicles Emission in Korea

The parts related to emission system is shown in Table 3, according to the vehicles.

**Table 3. Emission warranty period**

<Jan. 1, 2001 ~ Dec. 31, 2005>

Fuel	Class		Period <sup>1)</sup>		
	2001.1 ~ 2002.6	after 2002.7	2001.1 ~ 2002.6	2002.7 ~ 2002.12	after 2003.1
Gasoline	mini-car <sup>2)</sup>	mini-car	5y/80Kkm	5y/80Kkm	10y/160Kkm
	PC, multi-purpose vehicles	P1,P2	5y/80Kkm	5y/80Kkm	10y/160Kkm
			10y/160Kkm	10y/160Kkm	
	mid-sized vehicles	P3	5y/80Kkm	5y/80Kkm	5y/80Kkm
	large-sized vehicles	P4,	2y/80Kkm	2y/80Kkm	2y/160Kkm
Gas	two-wheeled vehicles (50cc or more)	two-wheeled vehicles (50cc or more)	1y/6Kkm	1y/6Kkm	2y/10Kkm
	mini-car <sup>2)</sup>	mini-car	5y/80Kkm	5y/80Kkm	10y/160Kkm
	PC, multi-purpose vehicles	P1,P2	5y/120Kkm	5y/120Kkm	10y/160Kkm
			10y/160Kkm	10y/160Kkm	
	mid-sized vehicles	P3,	5y/80Kkm	5y/80Kkm	5y/80Kkm
Diesel	large-sized vehicles	P4,	2y/80Kkm	2y/80Kkm	2y/160Kkm
	light-weight vehicles <sup>2)</sup>	light-weight vehicles	5y/80Kkm	5y/80Kkm	10y/160Kkm
	PC, multi-purpose vehicles	P1,P2	5y/80Kkm	5y/80Kkm	10y/160Kkm
	mid-sized vehicles	P3,T1,T2	5y/80Kkm	5y/80Kkm	5y/80Kkm
	large-sized vehicles	P4,T3	2y/80Kkm	2y/80Kkm	2y/160Kkm

**Remarks:**

1. Emission warranty period shall be based on the period or mileage, whichever occurs first.
2. Emission warranty period of coaches, vans, trucks and special feature vehicles is 5year/60,000km until Dec. 2002.
3. P1, P2, P3, P4: means small, medium, large, super large of passenger vehicle size  
T1, T2, T3, T4: means small, medium, large, super large of truck vehicle size

<After Jan. 1, 2006>

Fuel	class	period
Gasoline	mini-car	5y/80Kkm
	small-sized passenger cars	10y/160Kkm
	small-sized trucks, mid-sized passenger cars & trucks	10y/160Kkm
	large & extra large-sized passenger cars & trucks	2y/160Kkm
	two-wheeled vehicles (50cc or more)	2y/10Kkm
Gas	mini-car	5y/80Kkm
	small-sized passenger cars	10y/160Kkm
	small-sized trucks, mid-sized passenger cars & trucks	10y/160Kkm
	large & extra large-sized passenger cars & trucks	2y/160Kkm
Diesel	light-weight vehicles	5y/80Kkm
	small-sized passenger cars	5y/80Kkm
	small-sized trucks, mid-sized passenger cars & trucks	5y/80Kkm
	large & extra large-sized passenger cars & trucks	2y/160Kkm
	construction equipment	1y/20Kkm

## 8. The exhaust emission control standards (EECS) and Inspection of in-use vehicles in Korea<sup>8</sup>

### 8.1. Standards

The exhaust emission control standards of in-use vehicles are shown in Table 4. The emissions of CO and HC of gasoline-fueled vehicles are examined at idling, the visual inspection and the air to fuel ratio ( $\lambda$ ) of the vehicles respectively are conducted by the relevant regulation.

**The standards of  $\lambda$  are as follows.**

Vehicles equipped with the catalytic converter (electronic injection):  $1 \pm 0.10$

Vehicles equipped with the catalytic converter (carburetor):  $1 \pm 0.15$

Vehicles not equipped with the catalytic converter:  $1 \pm 0.20$

In case of Diesel fueled Vehicles, only smoke is measured in no load WOT.

<sup>8</sup> Korea MOE's Air Environment Protection Enforcement Regulation

**Table 4. The exhaust emission control standards of in-use vehicles**

Fuel	class			period	CO (%)	HC (ppm)	smoke <sup>1),2)</sup> (%)
	before 2000.12	2001.1 ~ 2002.6	after 2002.7				
Gasoline , LPG, Alcohol	mini- vehicles	mini- vehicles	mini- vehicles	before 1997.1	4.5	1,200	-
				1998.1 ~ 2000.12	2.5	400	
				2001.1 ~ 2002.6	1.2	220	
				after 2002.7	1.2	220	
	passenger cars	passenger cars	P1, P2	before 1987.1	4.5	1,200	-
				1988.1 ~ 200.12	1.2	220(400)	
				2001.1 ~ 2002.6	1.2	220	
				after 2002.7	1.2	220	
	small-sized trucks, heavy duty vehicles	-	-	1985.1 ~ 2000.12	4.5	1,200	-
	-	multi-purpose vehicles	-	2001.1 ~ 2002.6	2.5	400	
	-	heavy duty vehicles, large- sized vehicles	-	2001.1 ~ 2002.6	4.5	1,200	
	-	-	P3,P4, T1,T2,T3	after 2002.7	2.5	400	
Diesel	passenger cars, small- sized trucks	-	-	before 1995.12	-	-	40(2)
				1996.1 ~ 2000.12	-	-	35(2)
	-	passenger cars, multi- purpose vehicles, mid-sized vehicles	-	2001.1 ~ 2002.6	-	-	30(2)
	-	-	P1,2,3	after 2002.7	-	-	25(2)
	heavy-duty vehicles	-	-	before 1992.12	-	-	40(2)
				1993.1 ~ 1995.12	-	-	35(2)

### Vehicle Emission & Approval System

				1996.1 ~ 1997.12	-	-	30(2)
				1998.1 ~ 2000.12	city bus	-	25(2)
					others	-	30(2)
	-	large-sized vehicles	-	2001.1 ~ 2002.6	-	-	25(2)
	-	-	P4,	after 2002.7	-	-	20(2)

Remarks:

1. The values in ( ) mean the standards tested with a video camera.
2. 5% is added to the smoke standards of the diesel fueled vehicles attaching the turbocharger or intercooler.

## 8.2. Exhaust emission tests for in-use vehicles

### A. Regular Inspection

Automobile owners should take the regular test to confirm whether the in-use vehicle meet emission limits or not during the driving yeas. The term of validity of in-use vehicle exhaust emission is shown in Table 5.

**Table 5. The term of validity of vehicle inspection**

Vehicle Category	Year (Vehicle ages)	The term of validity(year)		
		1 <sup>st</sup> Test for after new vehicle's registration	Regular test	
			before change	after change
non-commercial passenger cars, trailer	less than 10	4	2	
	10 or more	-	2	
commercial vehicles	-	2	1	
light-duty & small-sized trucks	less than 10	1	1	
	10 or more	-	1	
commercial large-sized trucks	less than 2	1	1	
	2 or more	-	0.5	
other vehicles	less than 5	1	1	
	5 or more	-	0.5	

### B. Detail Inspection

At the test methods of the existing vehicle, regular inspection is conducted with no load engine running. Thus, the emissions do not represent real driving conditions, for example, the emissions of NOx are not properly measured. Therefore, the improvement of the test methods of NOx measurement is needed. As a result, the law has defined the two tests which consist of load test (ASM mode) and unload test (at idling) to measure the NOx emissions. The methods are the sensory test, the function test and the exhaust emission test.

Vehicles that are over 5.5 tons, regular 4WD and 2WD vehicles are conducted by the unloaded test.

The vehicles and the term of validity are shown in Table 6.

**Table 6. The vehicles for detail inspection and the term of validity**

Effective date Vehicle category		Before 2003.12	2004.1 ~ 2005.12	After 2006.1	the term of validity
Non-commercial	passenger cars	over 12 years	over 7 years	over 4 years	2
	others	over 7 years	over 5 years	over 3 years	1
commercial	passenger cars	over 3 years	over 2 years	over 2 years	1
	others	over 4 years	over 3 years	over 2 years	1

The load test of diesel fueled vehicles measures the smoke and vehicles which are over 5.5 tons are conducted by a light transmission analyzer with no load WOT.

#### C. Random exhaust emission inspection of in-use vehicle

This test is conducted to confirm the emission standard validity of in-use vehicles randomly, as shown in above **Table 4** (The exhaust emission control standards of in-use vehicles), on roads or in garages, and is performed by the control team of the cities and provinces.

Also, the comparison of inspection type for in-use vehicles is shown Table No 7.

**Table 7. Comparison of inspection type for in-use vehicles**

Items	Random exhaust emission inspection (on the road)	Regular inspection (Continuous inspection)
Inspection objectives	Detect & control in-use vehicles that exceed the limits, order to repairs	Maintain the limits until due date of inspection validity
Inspection method	Petrol vehicles: Idle Diesel vehicles: Free acceleration, Video recording	Petrol vehicles: Idle Diesel vehicles: Free acceleration
Inspection item	Petrol vehicles: CO, HC Diesel vehicles: Smoke	Petrol vehicles: CO, HC, $\lambda$ Diesel vehicles: Smoke
Authority of inspection	Provincial governor, City mayor, Special control team of City, province	Ministry of Environment or MOT, Certified test centers
Inspection vehicles	Random selection on the road	Vehicles that due date of inspection validity is approached (inspection validity: 0.5 ~ 1 year)

### 8.3. Inspection Method

#### (1) Petrol and Gas fueled vehicles

- a) Measuring method: at idle condition of engine
- b) Type-approved CO/HC measuring equipment that certified the calibration within 1 year from measuring date
- c) Analysis method: NDIR

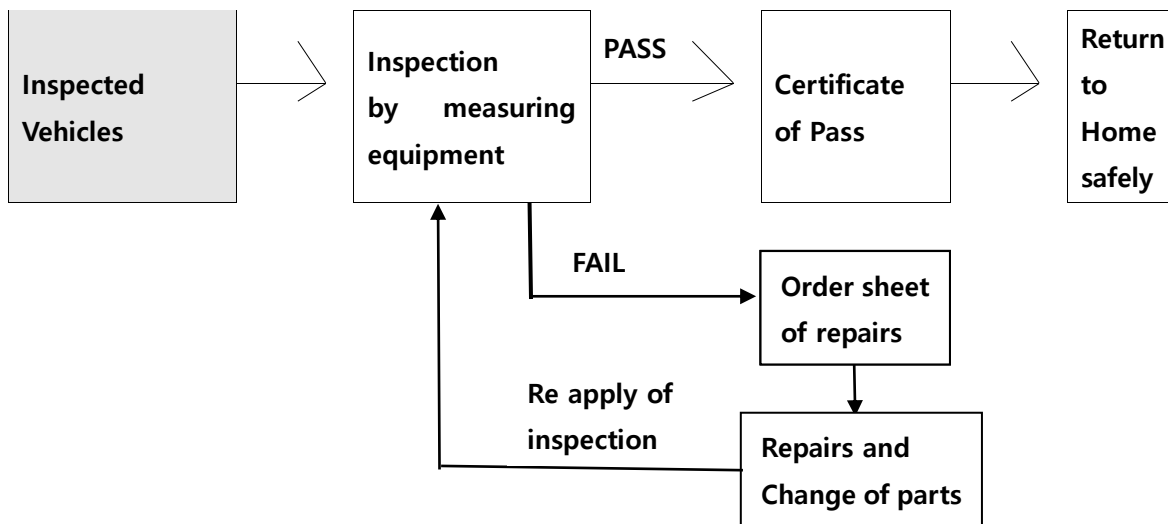
- d) Measuring units: CO (%), HC (ppm)
- e) Measuring range: CO (decimal first digit), HC (integer number)
- f) Measuring procedures
  - Operating the inspected vehicles normally at idle conditions
  - Inserting the pollutant receiver pipe to vehicle's exhaust pipe more than 30 cm
  - Measuring the CO, HC,  $\lambda$  after indicator of equipment is stabilizes
  - When exhaust pipes are two, select randomly and measure one exhaust pipe only
- g) Access air ratio ( $\lambda$ ): need to measure

**(2) Diesel fueled vehicles**

- a) Measuring method: at free acceleration (full load)
- b) Type-approved SMOKE meter that certified calibration within 1 year from measuring date
- c) Analysis method: Opacity
- d) Measuring units: Smoke (%)
- e) Measuring range: Integer number
- f) Measuring procedures
  - Exclude the smoke remained in the exhaust pipe of inspected vehicles
  - Inserting the pollutant receiver pipe to vehicle's exhaust pipe more than 20 cm
  - Footing the acceleration pedal quickly up to maximum rpm of engine
  - Measuring repeatedly the Smoke 3 times by same method

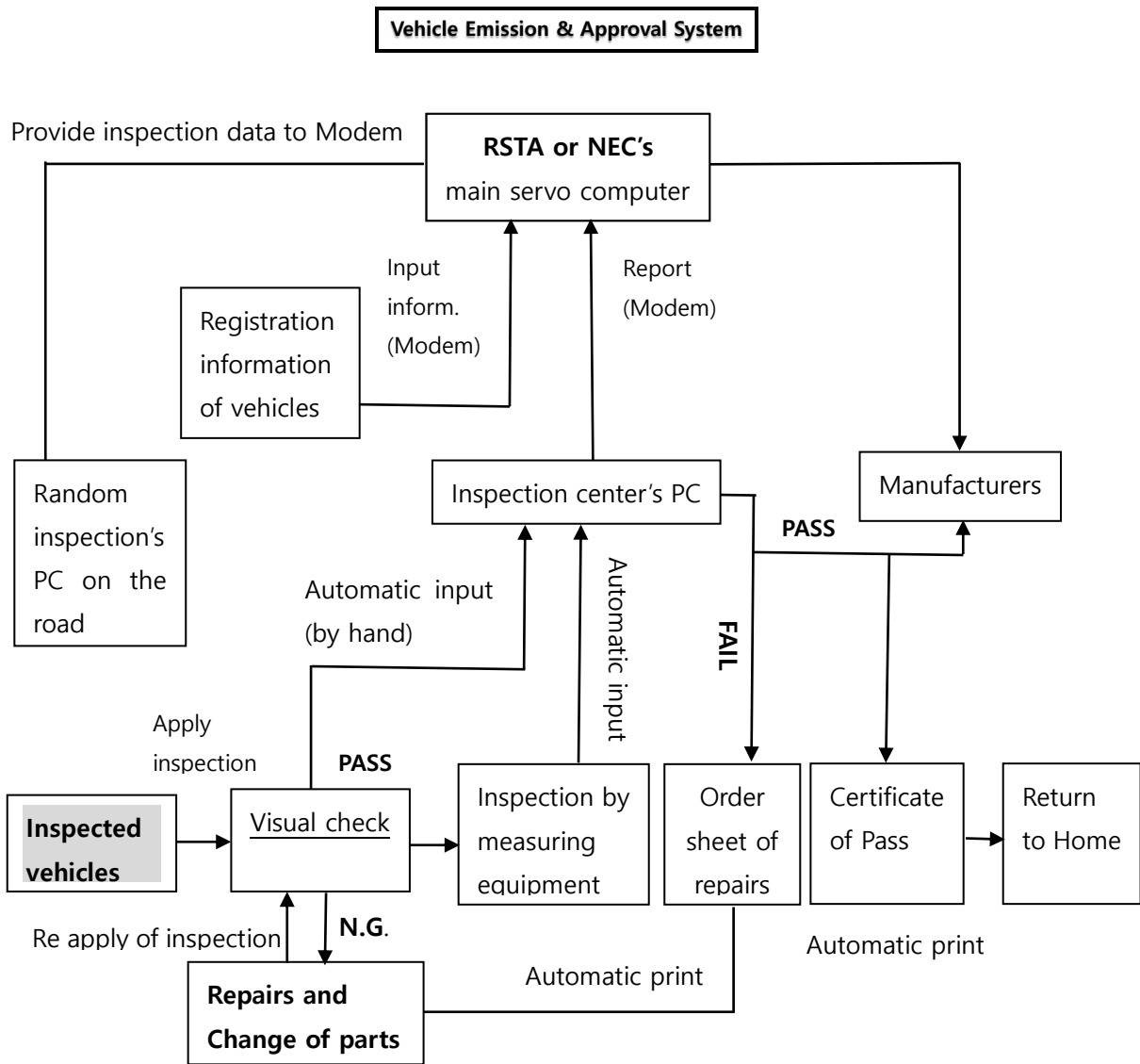
**8.4. Recommended inspection systems of in use vehicles for Bhutan**

(1) **Step 1** of Inspection flow chart:



(2) **Step 2** of Inspection flow chart:

**Step 2 is well organized and is able to control emission of in use vehicles strictly.**



**Table 8. Comparison of Step 1 and Step 2**

Items	Step 1 Inspection system	Step 2 Inspection system
Inspection items - Petrol Vehicles	CO, HC, $\lambda$	- CO, HC, NO <sub>x</sub> , CO <sub>2</sub> , O <sub>2</sub> - Visual check of emission components (Protection of intentional tampering)
- Diesel Vehicles	Smoke	Smoke
Inspection method - Petrol Vehicles	Measured at Idle of engine	Measured at load (by chassis dynamometer)
- Diesel Vehicles	Free acceleration	Free acceleration
Measuring equipment - Petrol Vehicles	Analyzer for CO/HC/ $\lambda$	Analyzer for CO/HC/NO <sub>x</sub> /CO <sub>2</sub> /O <sub>2</sub>
- Diesel Vehicles	Filtration type meter	Filtration type meter or Light transmission smoke meter
Management of	Issuing of report for inspection	Electronic control of inspection



### Vehicle Emission & Approval System

documents	results	results and vehicles history (Input the data to central main servo computer by PC network)
Inspection vehicles	Random selection on the road	Vehicles that due date of inspection validity is approached (inspection validity: 0.5 ~ 1 year)
Qualification of inspectors and repair engineers	Not available	- Training of repair and emission inspection - Grant of Certificate for certified inspector and repair technician

To implement Option 2 of inspection system for in use vehicles, the following items shall be performed by responsible Bhutan Government.

- (1) Training & Development of Inspection and repair program that are required for emission inspection for in use vehicles.
- (2) Conducting of visual checking for emission related components.
  - If any of intentional tampering for emission related components or not
  - If any of intentional breakage of seal for emission related systems or not
- (3) Adding of inspection items and Changing of inspection method
  - Idling test → Load Test,
  - Filtration type meter → Light transmission smoke meter
- (4) Installation of Electronic control system for inspection data and vehicles information (VIMS)
  - Making of data base for inspection data with vehicle's basic information
  - Protection of intentional tampering for test data by automatic input to electronic Network
  - Provide the inspection results for emission to India or vehicle manufacturers and push them to develop low emission vehicles.
  - Performing of correct inspection and repairs by granting the qualification to inspectors, repair technician and inspection centers
  - Conducting the periodic (regular) special training for inspectors and technician

## 9. Tightening fuel quality of automobiles in Korea <sup>9</sup>

### A. Gasoline fuel

The manufacturing standards of gasoline and diesel fuels for automobiles related to the emission systems are regulated by the law. The manufacturing standards of gasoline automobiles in Korea are shown in Table 9.

<sup>9</sup> Korea MOE's Air Environment Protection Enforcement Regulation

**Table 9. The manufacturing standards of gasoline**

Class \ Period	Before 2001. 12	2002. 1 ~ 2005.12	After 2006. 1
Aromatic Compounds (Volume %)	35 or less	35 or less	30 or less
Benzene content (Volume %)	2 or less	1.5 or less	1.0 or less
Pb content(g/ℓ)	0.013 or less	0.013 or less	0.013 or less
P content(g/ℓ)	0.0013 or less	0.0013 or less	0.0013 or less
O <sub>2</sub> content(mass%) <sup>1)</sup>	1.3 ~ 2.3	1.0 ~ 2.3	1.0 ~ 2.3
olefin content(Volume%) <sup>2)</sup>	23 or less	18(23) or less	18(21) or less
sulfur content(ppm) <sup>3)</sup>	200 or less	130 or less	50 or less
vapor pressure(kPa, 37.8°C) <sup>4)</sup>	82 or less	70 or less	65 or less
90% flow temperature(°C), T <sub>90</sub>	175 or less	175 or less	175 or less

Remarks:

1. 2.0 or less from April 1. to Oct. 31.
2. Applied to the standard in ( ) in case of aromatic compounds of 30 or less.
3. Mean 120 and Max. 150 in 2002.
4. Applied to 4.1 ~ 10.31 in 2001 and 6.1 ~ 8.31 2002 later.

The sulfur contents which have poisoned a catalytic converter are getting tightened by the severe regulation of exhaust emission. The emission warranty period is extended from 5years/80,000km to 10years/160,000km.

For the emission regulation of VOCs which have a high ozone forming ability, olefin hydrocarbons have been regulated since 2000.

## B. Diesel fuel

The main ingredients of light oil that affects the exhaust emission of the vehicles are the sulfur contents, aromatic compound contents, cetane number, density and 90% flow temperature (or 95% flow temperature). After the sulfur of light oil is transformed to the sulfurous acid during the combustion, it is exhausted to the air and increases the concentration of the sulfurous acid in the air. In case that an oxidation catalytic converter is used for a diesel-fueled vehicle converter, sulfurous acid is changed to sulfur trioxide and sulfur is changed to sulphate in the air, which increases the minute dust in the air. Moreover, the sulfurous acid of the exhaust emission reduces the durability of combustion systems and does the big damage to the performance of the catalytic converter. The production standards of light oil are shown in Table 10.

**Table 10. The production standards of Diesel**

### Vehicle Emission & Approval System

class \ year	before 2001	2002 1 ~ 2005.12.31	after 2006.1
10% remnants of carbon (%)	0.15 or less	0.15 or less	0.15 or less
sulfur(ppm)	500 or less	430 or less	30 or less
density@15°C (kg/m³)	-	815 ~ 855	-

## **10. Required Approval System for Vehicle Emission (Air Pollution) in Bhutan**

### 10.1. Objectives

Vehicles Emission and Approval System means that management systems are controlled by checking the information/technical documents and also by performing the tests/inspections for vehicles so that the authorized Government department can certify whether the exhaust gases and noises emitted from vehicles are conformed with the relevant regulations stipulated by Government or not, prior to manufacturing and selling of motor vehicles.

### 10.2. Legal Requirements and Responsibilities of Governments

The responsible Government department of Bhutan shall stipulate all regulations with regard to motor vehicle emission and approval system and also enforce the regulations strictly in order to save and protect air quality.

### 10.3. Types of Approval (Certification) <sup>10</sup>

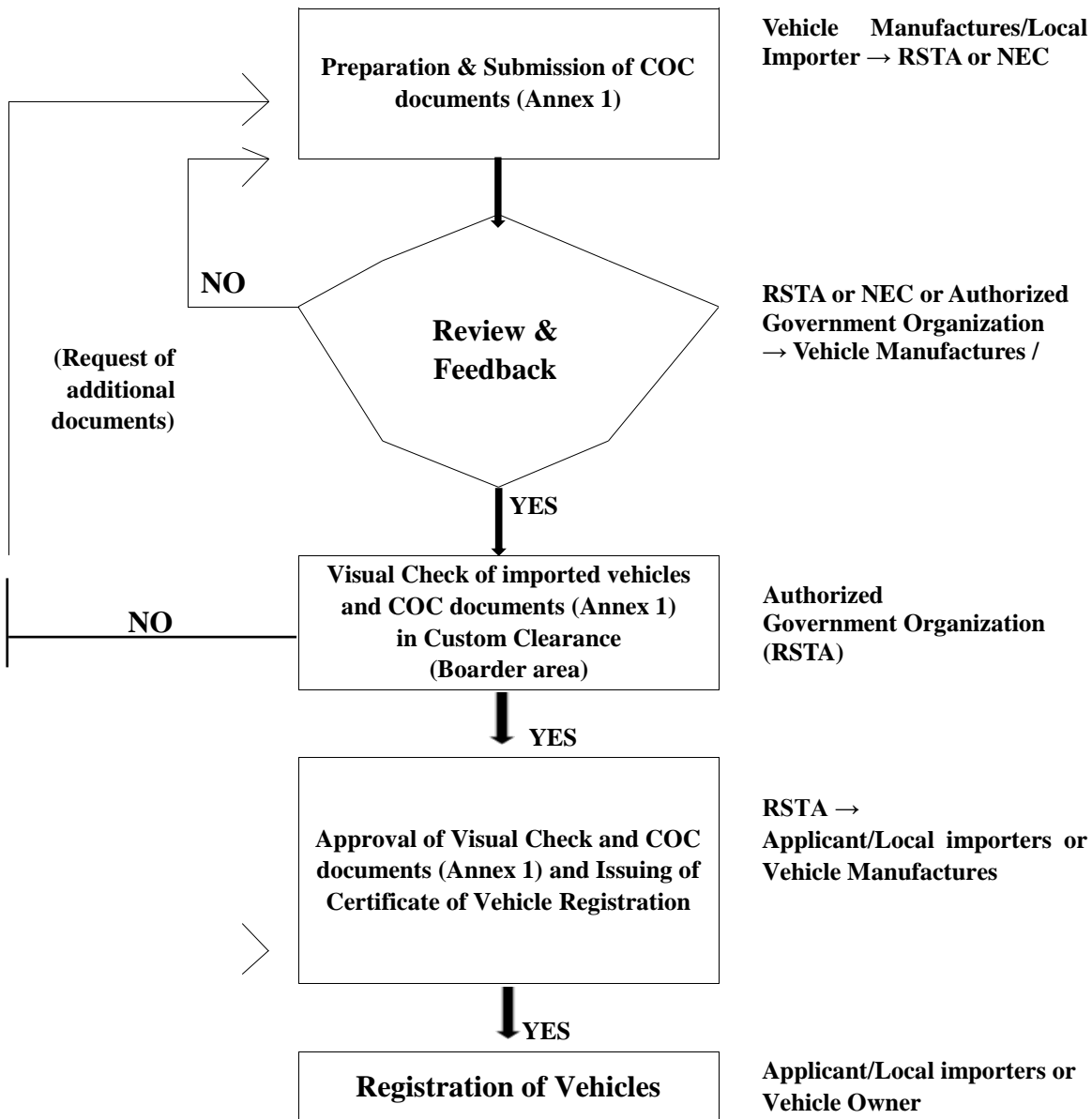
- (1) New Approval: For vehicle's family that have similar characteristics with regard to vehicle emission and noise (same family vehicles).
- (2) Extension Approval: For vehicles that have been changed with regard to emission system and its technical structures from already approved vehicles.
- (3) Omit of Approval: For small series vehicles having with below purposes
  - For national team and its training that confirmed by Sports Minister
  - For donated to Government organization or NGO from overseas, free of charge
  - For citizen who had lived more than 1 year overseas will take only 1 vehicle as a moving goods
  - For diplomat or foreign country soldier's family to be imported
  - For ground working of Airplane
  - For vehicles that Minister of Environment recognize to need omit of approval
- (4) Exemption of Approval: For vehicles having with below special purposes
  - For special purposes such as army and nation guard and fire extinguishing
  - For foreign country soldier who willing to use for public
  - For exporting or exhibition display that will be returned to foreign country soon
  - For traveler in conditions that will be returned to foreign country soon
  - For development or R&D, imported vehicles from foreign country by vehicle manufacturers or R&D laboratories
  - For zero emission vehicles such as electric, sun light, hydrogen vehicles

<sup>10</sup> Report: Understanding of Vehicle emission Type approval by Korea TPRC (1) (Transportation Pollution Research Center)

### 10.4. Inspection for in-use vehicles after approval

After approval, inspection of in-use vehicles is necessarily required to control the vehicles emission and maintain to meet continuously the limits during vehicle's using life time.

## 11. Required Approval Procedures in Bhutan



## 12. Required Test Method of Approval in Bhutan

Until the approval test facilities are installed by Authorized Government Organization, it is preferred that Bhutan Government to introduce and perform the vehicles emission and approval as per above No 11 Approval Procedures by visual checking of new imported vehicles and perfect reviewing of COC documents, required documents for registration at custom clearance, instead of approval tests.

But, it is more important thing that Bhutan Government shall install all test equipment and conduct the approval tests as soon as possible they can, like as other countries.

Even if the Bhutan Government cannot do approval tests at present due to not having test facilities,

I recommend the Bhutan Government to use the same test method of approval as Indian's at the same time, because emission limits and fuel standard are also the same as India's.

### **13. Proposals for Vehicle Emission and Approval System in Bhutan**

#### **13.1. Proposals for New Vehicles (Imported Vehicles)**

Until the approval test facilities for imported vehicles from overseas countries are installed by authorized Government organization (Until Bhutan Government are able to do approval tests), it is preferred that Bhutan Government shall introduce and perform the vehicles emission and approval, as per above No 11 Approval Procedures, 1) by visual checking of new imported vehicles (Annex 2: No.3 Visual Checking) and 2) reviewing of COC (Annex 1) documents and other 3) required registration documents (To be determined by Bhutan Government) at custom clearance (Boarder checking centers), on behalf of approval tests.

I recommend the Bhutan Government to use the same exhaust emission limits as below Indian's at the same time, because below fuel standard are also same as India's.

#### **Exhaust emission limits of India <sup>11</sup>**

<b>I N D I A</b> (All vehicle categories)	Indian test cycle : max speed is 90km/h compared to 120 km/h for the NEDC		
	<b>Bharat Stage IV - Euro 4</b>	From Apr 2010	National Capital Region (Dehli), 13 cities
		From Jul 2015 From Oct 2015	Above + plus 29 cities North India + bordering districts of Rajasthan (9 States)
		From Apr 2016	Western India plus + South and East India (10 States and Territories)
		<b>From Apr 2017</b>	<b>Nationwide</b>
	<b>Bharat Stage V - Euro 5</b>	From <b>Apr 2019</b> for new models, Apr <b>2020</b> for existing models	<b>Nationwide</b>
	<b>Bharat Stage VI-Euro 6</b>	From Apr <b>2021</b> for new models, Apr <b>2022</b> for existing models	<b>Nationwide</b>

#### **Fuel standard of India**

Fuel Type Effective Date	Diesel	Gasoline	Remarks
Jan.1, 2018	≤ 50 ppm sulfur	≤ 50 ppm sulfur	As of 2017: 350 ppm Diesel only imported
Jan.1, 2021	≤ 10 ppm sulfur	≤ 10 ppm sulfur	

#### **13.2. Proposals for In-Use Vehicle (See the previous page 18**

#### **“The exhaust emission control standards (EECS) and Inspection of in-use vehicles in Korea”)**

In order to control the emission pollutants from the in-use vehicles, above No. 8 the exhaust emission control standards (EECS) and Inspection of in-use vehicles shall be performed by Bhutan Government as soon as possible they can.

Also, Bhutan Government shall implement the below necessary action plan a.s.a.p.

<sup>11</sup> Worldwide Emissions Standards by Delphi

(1) Development of Inspection and repair program that are required for emission inspection for in use vehicles.

(2) Conducting of visual checking for emission related components.

- If any of intentional tampering for emission related components
- If any of intentional breakage of seal for emission related systems
- (3) Adding of inspection items and Changing of inspection method
  - Idling test → Load Test,
  - Filtration type meter → Light transmission smoke meter
- (4) Installation of Electronic control system for inspection data and vehicles information (VIMS)
  - Making of data base of inspected vehicle with vehicles specification/registration information.
  - Protection of intentional tampering for test data by automatic input to electronic VIMS.
  - Provide the inspection results for emission to vehicle manufacturers or local importer and do not permit the sales or import from vehicle manufacturers or local importer.
  - Performing of correct inspection and repairs by granting the qualification to inspectors, repair technician and inspection centers.
  - Conducting the periodic (regular) special training for inspectors and technician.

### **13.3. Proposals for electronic Vehicle Inspection Management System (VIMS)**

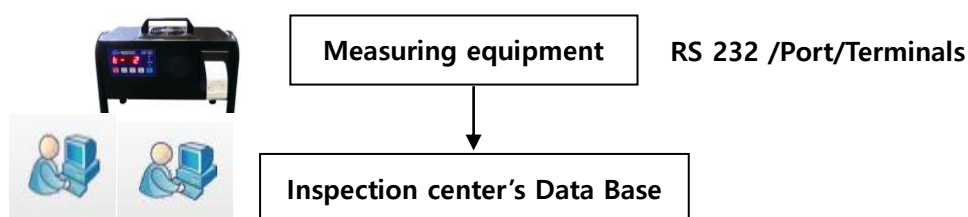
The Bhutan Government shall install the nationwide VIMS (Vehicle Inspection Management System) so that they can 1) perform the emission inspection for in-use vehicles efficiently and can 2) standardize of inspection works and can 3) operate vehicle inspection management system stably such as automatic transmission for inspection data and vehicle information, after test center have inspected the in-use vehicles.

#### **• Flow chat of Installation for VIMS (Vehicle Inspection Management System)**

##### **1) 1<sup>st</sup> Stage (Initial Installation)**

- a) Installation of system that can save the test data from each measuring equipment to inspection center's data base: This means that the RS 232 terminals of existing measuring equipment shall be connected to inspection center's computers.
- b) It is confirmed that the manufacturer of measuring equipment can provide the program of this system
- c) The computer program shall input the test data as well as vehicle's specifications and registration information such as below.
  - Vehicle name, registration No, VIN, vehicle category, owner name/address, model year, length, height, gross vehicle weight (GVW), etc.
  - Inspection data (Test results)

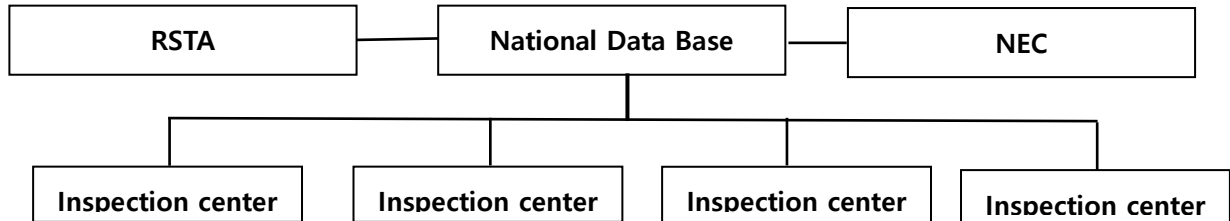
#### **System flow chart of 1st Stage (Initial Installation)**



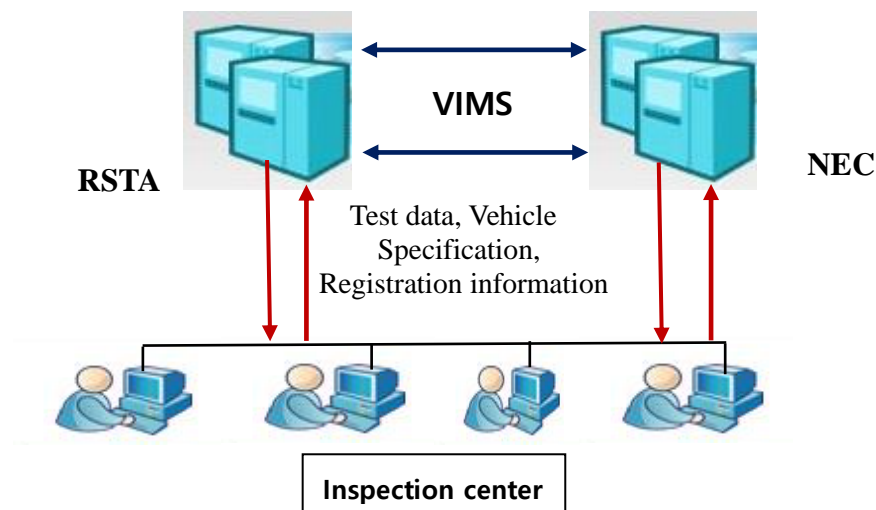
##### **2) 2<sup>nd</sup> Stage (Finally Complete Installation: Installation of VIMS)**

VIMS shall provide the basic information of vehicles to the each inspection center so that inspection center can do inspection test.

- a) The each inspection center shall input the test data and vehicle's specifications and registration information to National data base controlled by RSTA and NEC.
- ※ The Bhutan Government shall make additional computer program and install it nationwide (VIMS).
- b) It is confirmed that the manufacturer of measuring equipment can provide the program of this system, if needed.



**System flow chart of 2nd Stage (Installation of VIMS)**



(Regular, Detail, Random inspections of in use vehicles)

#### **13.4. Proposals for Emission warranty period of Vehicles Emission in Bhutan (See the previous page 17 “Emission warranty period of Vehicles Emission in Korea”)**

I also recommend Bhutan Government will introduce emission warranty period of vehicles emission after Vehicle Emission and Approval System for new vehicles (imported vehicles) and in use vehicles are stable and well managed and controlled by Bhutan Government.

This is why that emission warranty period with regard to emission related components are very important in order to reduce the air pollution emitted from vehicles.

COMPLETE AND COMPLETED VEHICLES

MODEL A1 – SIDE 1

COMPLETE VEHICLES

EC CERTIFICATE OF CONFORMITY

Side 1

The undersigned: [.....] (*Full name and position*) hereby certifies that the vehicle:

0.1. Make (Trade name of manufacturer): .....

0.2. Type: .....

Variant<sup>(a)</sup>: .....

Version<sup>(a)</sup>: .....

0.2.1. Commercial name: .....

0.4. Vehicle category: .....

0.5. Company name and address of manufacturer: .....

0.6. Location and method of attachment of the statutory plates: .....

Location of the vehicle identification number: .....

0.9. Name and address of the manufacturer's representative (if any): .....

0.10. Vehicle identification number: .....

conforms in all respects to the type described in approval (... *type-approval number including extension number*) issued on (..... *date of issue*) and

can be permanently registered in Member States having right/left<sup>(b)</sup> hand traffic and using metric/imperial<sup>(c)</sup> units for the speedometer<sup>(d)</sup>.

(Place) (Date): ...

(Signature): .....

<sup>12</sup> EEC 2015/758, ANNEX IX



VEHICLE CATEGORY M<sub>1</sub>

(complete and completed vehicles)

Side 2

General Construction Characteristics

1. Number of axles: ..... and wheels: .....
3. Powered axles (number, position, interconnection): .....

Main Dimensions

4. Wheelbase<sup>(e)</sup>: ..... mm
- 4.1. Axle spacing: 1-2 ..... mm      2-3 ..... mm      3-4 ..... mm
5. Length: ..... mm
6. Width: ..... mm
7. Height: ..... mm

Masses

13. Mass in running order: ..... kg
- 13.2. Actual mass of the vehicle: ..... kg
16. Technically permissible maximum masses
- 16.1. Technically permissible maximum laden mass: ..... kg
- 16.2. Technically permissible mass on each axle: 1 ..... kg      2 ..... kg      3 ..... kg etc.
- 16.4. Technically permissible maximum mass of the combination: ..... kg
18. Technically permissible maximum towable mass in case of:
- 18.1. Drawbar trailer: ..... kg
- 18.3. Centre-axle trailer: ..... kg
- 18.3. Centre-axle trailer: ..... kg
- 18.4. Un-braked trailer: ..... kg
19. Technically permissible maximum static vertical mass at the coupling point: ..... kg

### Power Plant

20. Manufacturer of the engine: .....
21. Engine code as marked on the engine: .....
22. Working principle: .....
23. Pure electric: yes/no<sup>(1)</sup>
- 23.1. Hybrid [electric] vehicle: yes/no<sup>(1)</sup>
24. Number and arrangement of cylinders: .....
25. Engine capacity: ..... cm<sup>3</sup>
26. Fuel: Diesel/petrol/LPG/CNG–Biomethane/LNG/Ethanol/Biodiesel/Hydrogen<sup>(1)</sup>
- 26.1. Mono fuel/Bi fuel/Flex fuel/Dual-fuel<sup>(1)</sup>
- 26.2. (Dual-fuel only) Type 1A/Type 1B/Type 2A/Type 2B/Type 3B<sup>(1)</sup>
27. Maximum power
- 27.1. Maximum net power<sup>(9)</sup>: ..... kW at ..... min<sup>-1</sup>  
(internal combustion engine)<sup>(1)</sup>
- 27.2. Maximum hourly output: ..... kW (electric motor)<sup>(1)</sup>
- 27.3. Maximum net power: ..... kW (electric motor)<sup>(1)</sup>
- 27.4. Maximum 30min power: ..... kW (electric motor)<sup>(1)</sup>

### Maximum Speed

29. Maximum speed: ..... km/h

### Axles and Suspension

30. Axle(s) track: 1. .... mm 2. .... mm 3. .... mm
35. Tyre/wheel combination<sup>(h)</sup>: .....

### Brakes

36. Trailer brake connections mechanical/electric/pneumatic/hydraulic<sup>(1)</sup>

### Bodywork

38. Code for bodywork<sup>(i)</sup>: .....
40. Colour of vehicle<sup>(i)</sup>: .....
41. Number and configuration of doors: .....
42. Number of seating positions (including the driver)<sup>(k)</sup>: .....
- 42.1. Seat(s) designated for use only when the vehicle is stationary: .....
- 42.3. Number of wheelchair user accessible position: .....

### Environmental Performances

46. Sound level
- Stationary: ..... dB(A) at engine speed: ..... min<sup>-1</sup>
- Drive-by: ..... dB(A)
47. Exhaust emission level<sup>(l)</sup>: Euro .....
48. Exhaust emissions<sup>(m)(m1)(m2)</sup>: .....
- Number of the base regulatory act and latest amending regulatory act applicable: .....
- 1.1. test procedure: Type I or ESC<sup>(1)</sup>
- CO: ..... HC: ..... NO<sub>x</sub>: ..... HC + NO<sub>x</sub>: ..... Particulates: .....
- Smoke opacity (ELR): ..... (m<sup>-1</sup>)
- 1.2. test procedure: Type I (Euro 5 or 6<sup>(1)</sup>) or WHSC (Euro VI)<sup>(1)</sup>
- CO: ..... THC: ..... NMHC: ..... NO<sub>x</sub>: ..... THC + NO<sub>x</sub>: .....
- NH<sub>3</sub>: ..... Particulates (mass): .....
- Particles (number): .....
- 2.1. test procedure: ETC (if applicable)
- CO: ..... NO<sub>x</sub>: ..... NMHC: ..... THC: ..... CH<sub>4</sub>: ..... Particulates: .....
- 2.2. test procedure: WHTC (Euro VI)
- CO: ..... NO<sub>x</sub>: ..... NMHC: ..... THC: ..... CH<sub>4</sub>: ..... NH<sub>3</sub>: .....
- Particulates (mass): ..... Particles (number): .....
- 48.1. Smoke corrected absorption coefficient: ..... (m<sup>-1</sup>)

49. CO<sub>2</sub> emissions/fuel consumption/electric energy consumption<sup>(m)</sup>:

1. all power train except pure electric vehicles

	CO <sub>2</sub> emissions	Fuel consumption
Urban conditions:	..... g/km	..... l/100km/m <sup>3</sup> /100km <sup>(1)</sup>
Extra-urban conditions:	..... g/km	..... l/100km/m <sup>3</sup> /100km <sup>(1)</sup>
Combined:	..... g/km	..... l/100km/m <sup>3</sup> /100km <sup>(1)</sup>
Weighted, combined	..... g/km	..... l/100km

2. pure electric vehicles and OVC hybrid electric vehicles

Electric energy consumption (weighted, combined<sup>(1)</sup>) ..... Wh/km

Electric range ..... km

3. Vehicle fitted with eco-innovation(s): yes/no<sup>(1)</sup>

3.1. General code of the eco-innovation(s)<sup>(p1)</sup>: .....

3.2. Total CO<sub>2</sub> emissions savings due to the eco-innovation(s)<sup>(p2)</sup> (repeat for each reference fuel tested): .....

#### Miscellaneous

51. For special purpose vehicles: designation in accordance with Annex II Section 5: .....

52. Remarks<sup>(n)</sup>: .....

**Annex 2:** Inspection Test Report of in-use vehicles <sup>13</sup>

**Inspection Test Report of In-use vehicles**

Inspection Date: 12 day, May month, 2017 year

<b>Vehicle Registration No.</b>	ACX B4321	<b>Owner Name</b>	James Miller	<b>Vehicle Name</b>	SONATA 2.0
<b>V.I.N</b>	KMHFF42CBBA076361	<b>Engine Type</b>	G4KJ	<b>First Registration Date</b>	17. May, 2014
<b>Next Inspection Date</b>	16. May, 2019	<b>Re-Inspection Date</b>		<b>Mileages</b>	42,178 km

The vehicle needed for Re-Inspection shall be re-inspected until due date.  
If the owner do not re-inspection, he will receive the fine ticket (USD 60.00).

Inspection Item	Inspection Limits		Inspection Results	Inspection Overview	Inspector
1. Emission Gasoline/ LPG	Test Method		Free TSI	Generally good	Bill Clinton
	CO	≤ 1.00 %	0.00/0/00 %		
	HC	≤ 120 ppm	0/8 ppm		
	NOx	-	-		
	Access air ratio (λ)	0.90 ~ 1.10	1.08/1.03		
Diesel	Test Method		Free Acceleration	Improvement is needed	Trump Pence
	Smoke	≤ 40.0 %	31.0 %		
	Max. Engine Output	-	260 PS		
	Engine RPM	-			
2. OBD	Diagnostic Item Engine RPM, Sensor of cooling water, Sensor of intake pressure(MAP), Sensor of full open throttle, O2 Sensor, Injection Timing, Operation of fuel pressure control, ABS	Mal function Code			Smith
		Inspection Overview: Good			
3. Visual Checking	Contamination Rate of Engine Oil		Good	Visual checking for vehicle are generally good.	Obama
	Yes or No of Tampering, Vehicle frame/body, load devices		Good		
	Horn, Towing Hook, electric device		Good		
	Fuel system, Wind shield glasses		Good		
	Tampering of emission related components		Good		
	Other Devices				

<sup>13</sup> Korea MOT's Vehicle Management Control Act Article No 43, 44,45

4. Overall Inspection Results	Generally your vehicle is good and well maintained by regularly changing of oil, etc. Please drive safety tour vehicle.
Fail Contents (Re-Inspection is needed)	EGR is not working. Need to change new one.

Inspection Date: 12, May, 2017.

RSTA, THIMPHU INSPECTION CENTER Name/Address,

Contact Information,

Responsible Inspector:  
Bill Clinton (Signature)

**Annex 3: Certificate of Vehicle Registration <sup>14</sup>**

**Certificate of Vehicle Registration**

No 201108- 00073

First Registration Date: 17, May 2014

<b>Vehicle Registration No</b>	ACX B4321	<b>Vehicle Category</b>	Large PC	<b>U S e</b>	Private/ Commercial																					
<b>Vehicle Name</b>	SONATA	<b>Type &amp; Model Year</b>	HGCBA-B & 2014																							
<b>V.I.N</b>	KMHFF42CBBA076361	<b>Engine Type</b>	G4KJ																							
<b>Registration Address</b>	678,Thimphu, ZIP 12345																									
<b>Owner</b>	Name	Lincoln Adams	<b>Owner(Company) Identification No.</b>	213-69-3214																						
	Address	678,Thimphu, ZIP 12345																								
We certify here the above vehicle is registered according RSTA's Act Regulation No 17																										
17 day May Month 2014 Year																										
<p>•Notice: When the owner name &amp; address are changed, owner shall re-apply the changing in detail within 15 days</p> <p style="text-align: right;"><b>Mayor of Thimphu (Signature)</b></p>																										
<b>Vehicle Specification</b>				<b>Inspection Due Date</b>																						
<b>Approval (Control) No.:</b> A09-1-0076-0000-1321				<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%;"><i>From day, month, year</i></td> <td style="width: 33%;"><i>To day, month, year</i></td> <td style="width: 33%;"></td> </tr> <tr> <td>17. May, 2017</td> <td>16. May, 2019</td> <td></td> </tr> <tr> <td>10. May, 2019</td> <td>16. May, 2021</td> <td>Next Inspec. Date</td> </tr> <tr> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> </tr> </table>		<i>From day, month, year</i>	<i>To day, month, year</i>		17. May, 2017	16. May, 2019		10. May, 2019	16. May, 2021	Next Inspec. Date												
<i>From day, month, year</i>	<i>To day, month, year</i>																									
17. May, 2017	16. May, 2019																									
10. May, 2019	16. May, 2021	Next Inspec. Date																								
<i>Length</i>	4910 mm	<i>Width</i>	1860mm																							
<i>Height</i>	1470 mm	<i>GVW</i>																								
<i>CC</i>	2359 cc	<i>Engine Output</i>	201/6300 Ps/rpm																							
<i>No of Cylinder</i>	4 cylinder	<i>Type of Fuel</i>	Diesel / <del>Un-lead Gasoline</del>																							
<i>No of Occupants</i>	5 persons	<i>Fuel Consumption</i>	12.8 km/L																							
<i>Others</i>																										
Vehicle Purchasing Price (VAT excluding): \$ 3,200.00																										

<sup>14</sup> Korea MOT's Vehicle Management Control Act Article No 8

#### Annex 4: Exhaust emission limits of India <sup>15</sup>

<b>I N D I A</b> (Including all categories vehicles)	Indian test cycle : max speed is 90km/h compared to 120 km/h for the NEDC		
	Bharat Stage IV-Euro 4	From Apr 2010	National Capital Region (Dehli), 13 cities
		From Jul 2015	Above + plus 29 cities
		From Oct 2015	North India + bordering districts of Rajasthan (9 States)
		From Apr 2016	Western India plus + South and East India (10 States and Territories)
		From Apr 2017	Nationwide
	Bharat Stage V-Euro 5	From Apr 2019 for new models, Apr 2020 for existing models	Nationwide
	Bharat Stage VI-Euro 6	From Apr 2021 for new models, Apr 2022 for existing models	Nationwide

##### 1. PC (Passenger Vehicle: M1)

Stage	Fuel Type	CO	HC+Nox	NOx	PM	Bhutan's Effective Date/(EU's)
Euro 3	Gasoline	2.3	0.2(HC)	0.15	2.0(Evap)	
	Diesel	0.64	0.56	0.5	0.05	(2005)
Euro 4	Gasoline	1.0	0.1(HC)	0.08	2.0(Evap)	-
	Diesel	0.5	0.3	0.25	0.025	2017/(2006)
Euro 5	Gasoline	1.0	0.1(HC) 0.068(NMHC)	0.06	-	2019/(-)
	Diesel	0.5	0.17	0.08	0.005	2019/(2009)

##### 2. Light Duty Truck (LDT: M1) for Diesel only

Stage	Reference Weight	CO	THC+Nox	NOx	PM	Bhutan's Effective Date/(EU's)
Euro 3	RM ≤ 1.76t	0.80	0.72	0.65	0.07	-/(2005)
	RM > 1.76t	0.95	0.86	0.78	0.10	
Euro 4	RM ≤ 1.76t	0.63	0.39	0.33	0.04	2017/(2005)
	RM > 1.76t	0.74	0.46	0.39	0.06	
Euro 5	RM ≤ 1.76t	0.50	0.23	0.18	0.05	2019/(2009)
	RM > 1.76t	0.63	0.30	0.24	0.05	

RM (Reference Mass): CVW (Curb Vehicle Weight) + 100kg

<sup>15</sup> Worldwide Nation's Emissions Standard by Delphi



### 3. Heavy Duty Vehicles (M2, M3, N2, N3) for Diesel only

Stage	Test Method	CO	THC	NOx	PM	Smoke	Bhutan's Effective Date/(EU's)
Euro 3	ND-13(ESC)	2.10	0.66	5.0	0.10	0.8	
	ETC	5.45	0.78(NMHC)	5.0	0.16	-	
Euro 4	ND-13(ESC)	1.50	0.46	3.50	0.02	0.5	
	ETC	4.0	0.55 (NMHC)	3.50	0.03	-	
Euro 5	ND-13(ESC)	1.50	0.46	2.00	0.22	-	
	ETC	4.0	0.55(NMHC)	2.00	0.03		

**Annex 5: Fuel standard of India**

Fuel Type Effective Date	Diesel	Gasoline	Remarks
Jan.1, 2018	$\leq 50$ ppm sulfur	$\leq 50$ ppm sulfur	As of 2017: 350 ppm Diesel imported only
Jan.1, 2021	$\leq 10$ ppm sulfur	$\leq 10$ ppm sulfur	

**1. Indian Diesel Specification required to meet Bharat Stage II, III, IV Emission Norms <sup>16</sup>**

Characteristics	Unit	Bharat Stage III	Bharat Stage IV	Bharat Stage VI
Implementation date		2005 (selected cities) 2010 (nationwide)	2010 (selected cities) 2017 (nationwide)	2020(nationwide)
Ash, max	% mass	0.01	0.01	0.01
Carbon Residue, max	% mass	0.3	0.3	0.3
Cetane No (CN), min	-	51	51	51
Cetane Index (CI), min	-	46	46	46
Flash point Abel, min	°C	35	35	35
Density @15°C	kg/m <sup>3</sup>	820~845	820~845	820~860
<b>Total Sulfur, max</b>	<b>mg/kg</b>	<b>350</b>	<b>50</b>	<b>10</b>
Water content, max	mg/kg	200	200	200
Cold filter plugging point (CFPP)				
a) Summer, max	°C	18	18	18
b) Winter, max		6	6	6
Total contaminations, max	mg/kg	24	24	24
Oxidation stability, max	g/mg <sup>3</sup>	25	25	25
Polyaromatic Hydrocarbon(PAH),max	% mass	11	11	11

**2. Indian Gasoline Specification required to meet Bharat Stage II, III, IV Emission Norms <sup>17</sup>**

Characteristics	Unit	Bharat Stage III	Bharat Stage IV	Bharat Stage VI
Implementation date		2005 (selected cities) 2010 (nationwide)	2010 (selected cities) 2017 (nationwide)	2020(nationwide)
Lead, max	g/L	0.005	0.005	0.005
Motor Octane No(MON),	min	81	81	81/85
Octane No(ROD),	min	91	91	91/95
Reid Vapor Pressure(RVP)	kPa	60	60	60
Density @15°C	kg/m <sup>3</sup>	720~775	720~775	720~775
<b>Total Sulfur, max</b>	<b>ppm</b>	<b>150</b>	<b>50</b>	<b>10</b>
Oxygen Content, max	% mass	2.7	2.7	2.7

<sup>16/17</sup> India: Fuels: Diesel and Gasoline – Transport policy.net by Internet Google Search

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