UFP Health Effects and Diesel Particle Technologies. Theory and Practical Applications – Experiences from retrofit activities in Tehran

AQM 2016 , VERT Workshop, Hossein Izanloo

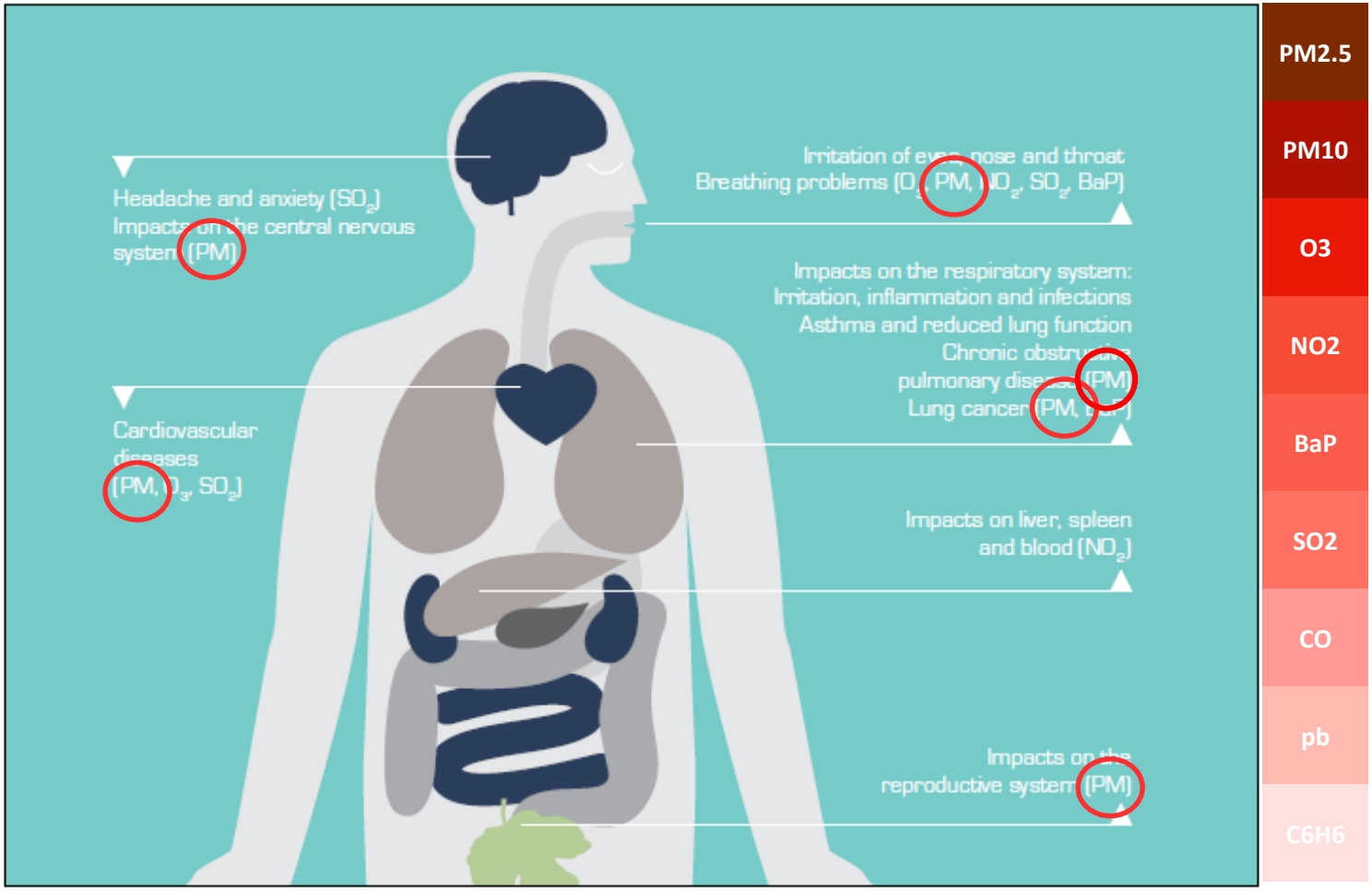
Key Topics

- Requirements for successful retrofit
- Case study Tehran retrofit
- Learning and best practice for Iran retrofit program

Experiences from Retrofit Activities in Tehran / Requirements

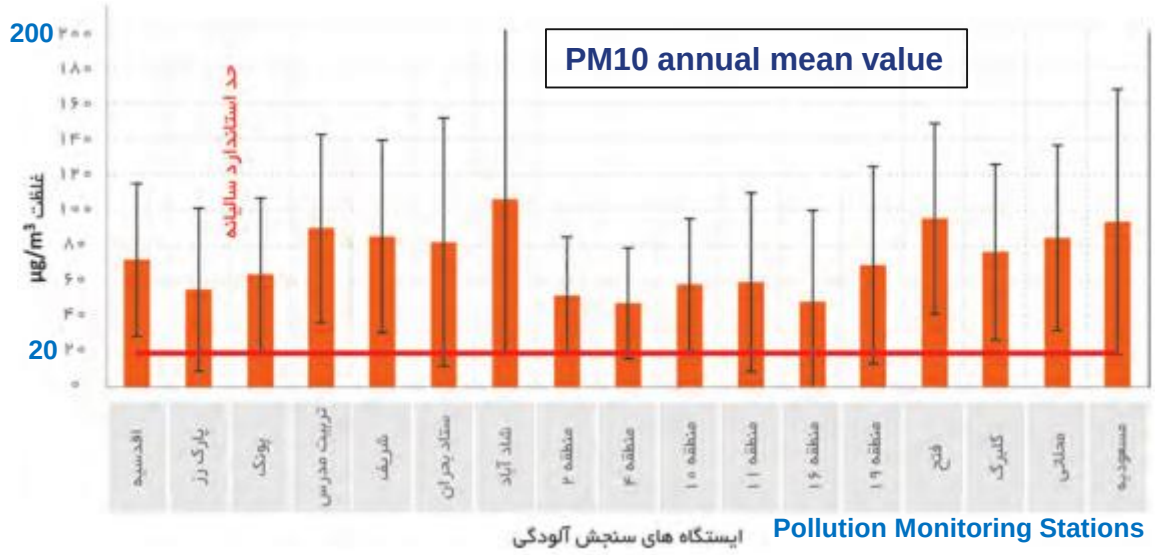
The Problem

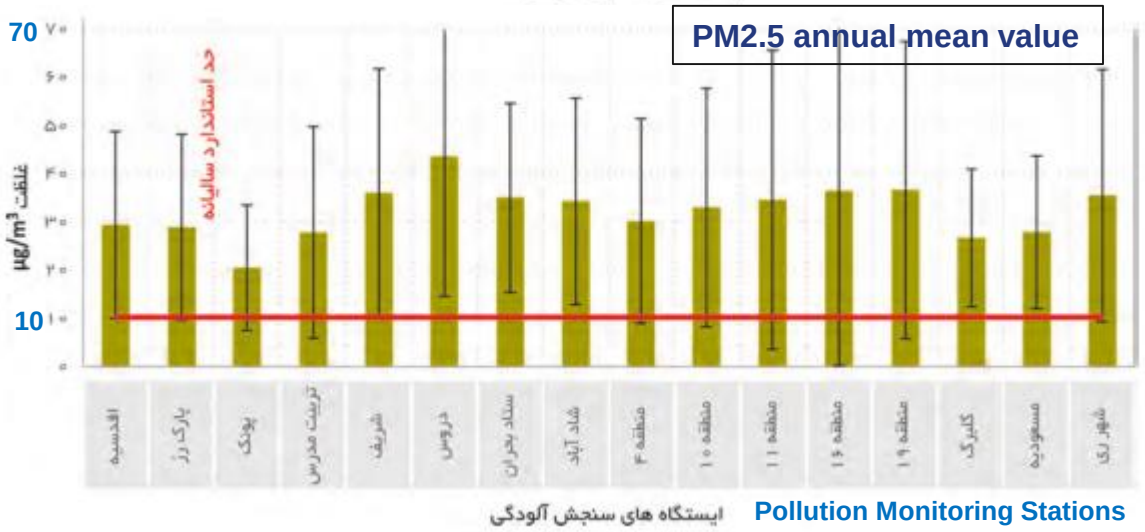
Air Pollutants and Their Health Impacts



Source: Air quality in Europe – 2013 report, European Environment Agency

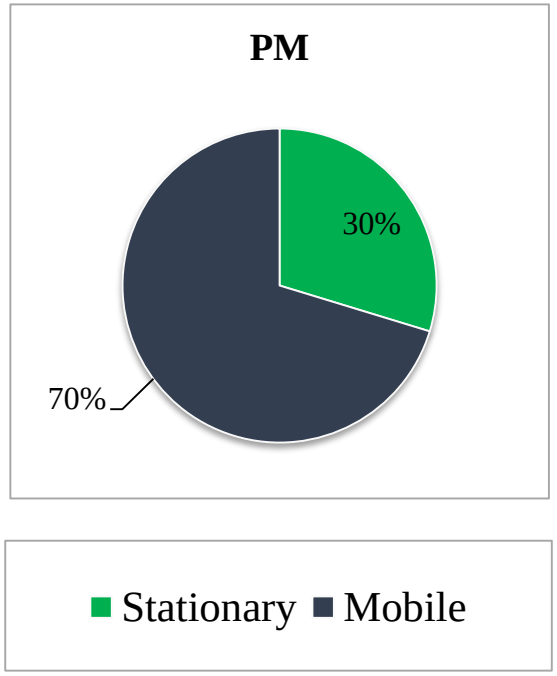
Tehran PM problem

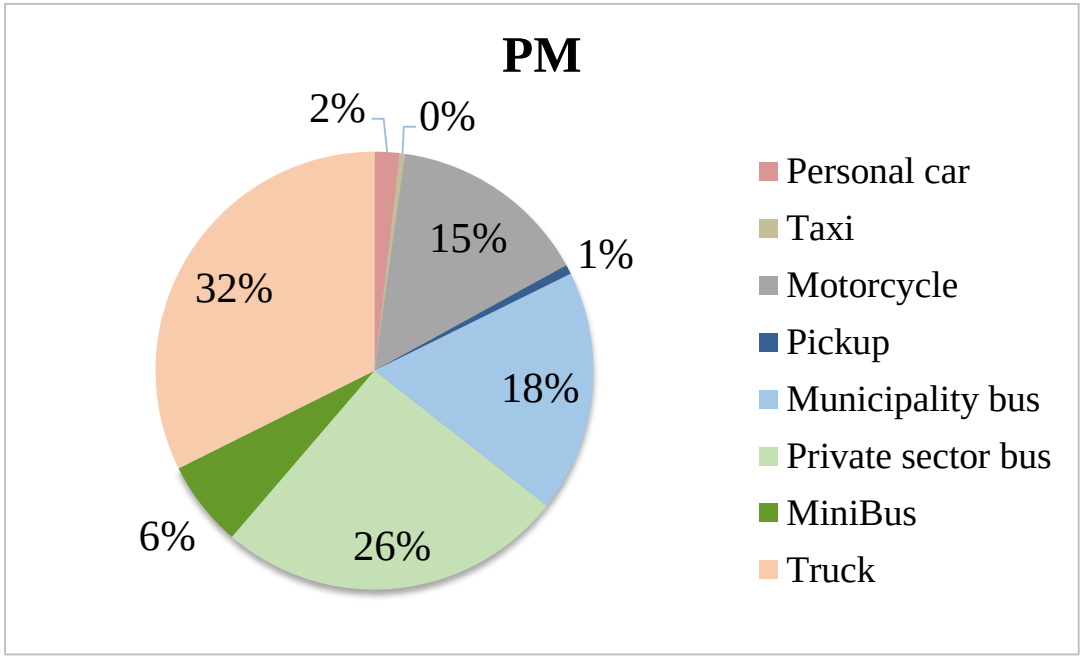




منبع: شرکت کنترل کیفیت هوا، گزارش سالانه کیفیت هوای تهران در سال 1393، QM94/02/02(U)/1، خرداد ماه 1394

Contributions of Tehran Primary PM Sources





منبع: شرکت کنترل کیفیت هوا، سیاهه انتشار آلایندگی شهر تهران برای سال مبنای 1392- جلد دوم: منابع متحرک

Experiences from Retrofit Activities in Tehran / Requirements

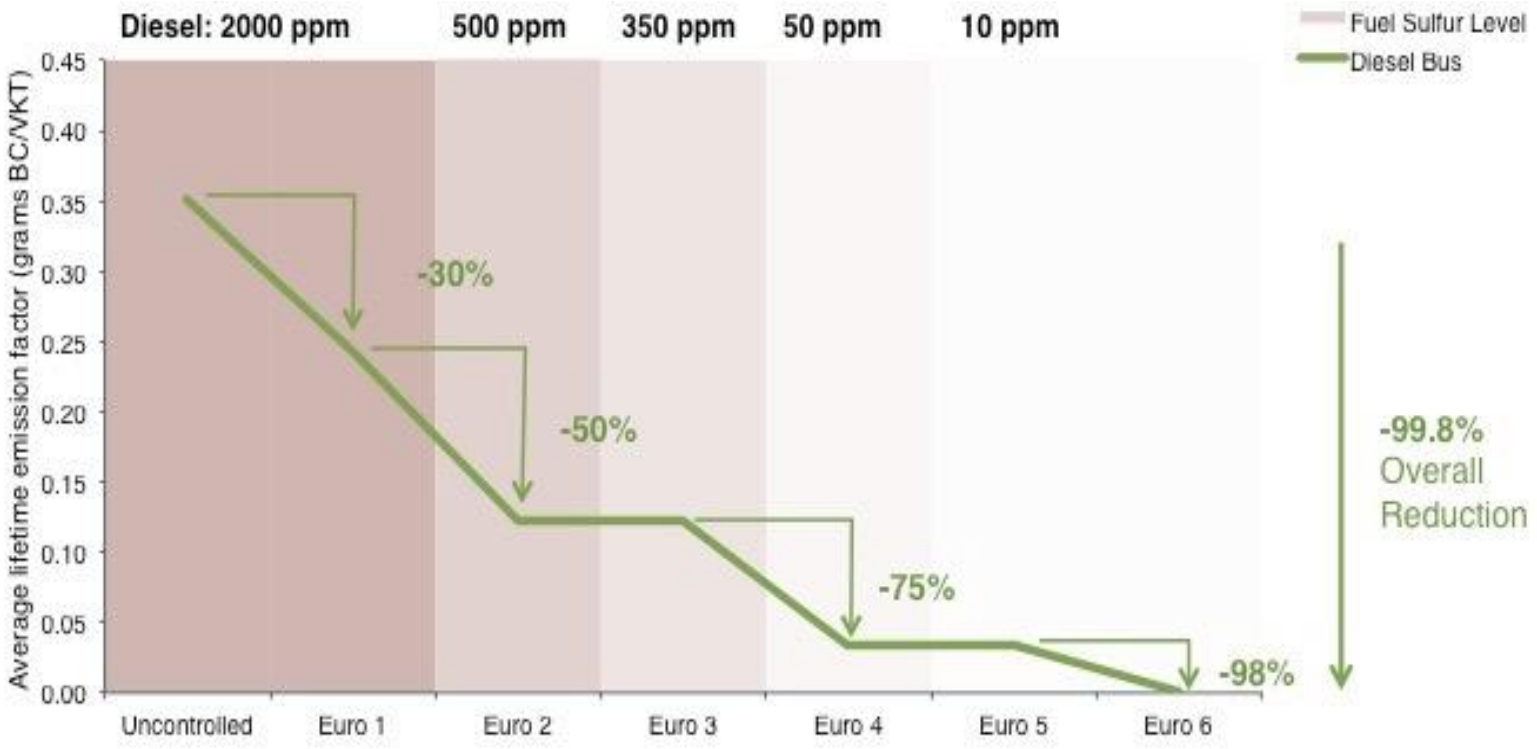
The Solution

Fuel and Particulate Filter

Low Sulfur Diesel Fuel

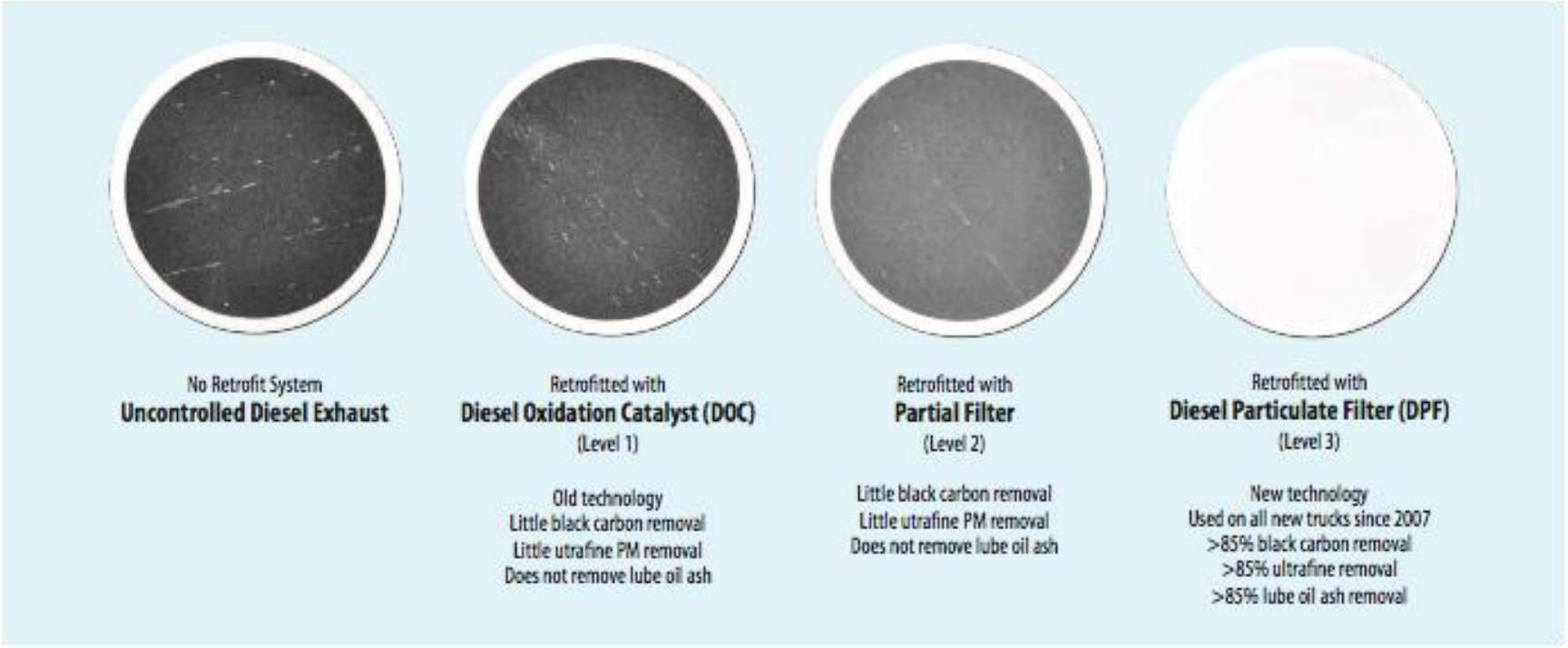
Theory of Change

Stages of Black Carbon Emissions Control Based on European Regulatory Approach to Urban Bus Fleets (Source: COPERT Emissions Model)



Source: ICCT, Soot-free urban bus fleet report, 2015

Technology Shift Towards Emissions Control



Overview: The exhibits above are actual PM collection samples from an engine testing laboratory used to collect and measure diesel particulate matter (PM) emissions. Test conditions are:

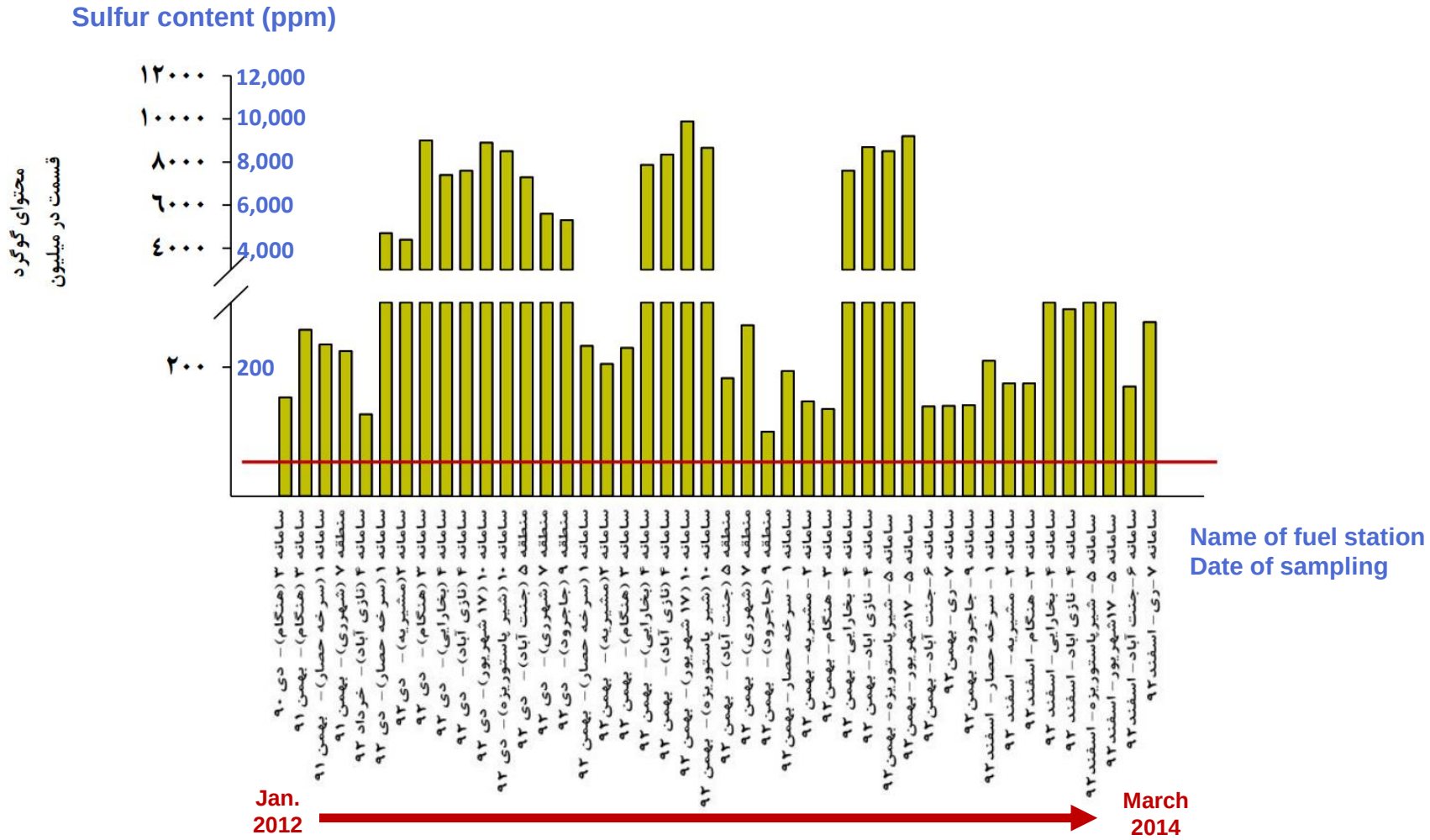
- Test Cycle: UDDS (Urban Dynamometer Driving Schedule)
- Test Distance: 5.5 miles over 17 minutes
- Fuel Consumed During Test: 1.1 gallons
- Test Vehicle: Heavy-duty truck with a 370 hp Cummins engine (1999 model year)
- PM material on collection samples is 1/1,800th of actual

Source: ICCT, Soot-free urban bus fleet report, 2015

Experiences from Retrofit Activities in Tehran / Requirements

The Challenge

Diesel Fuel Sulfur Content of Tehran BRT Fleet

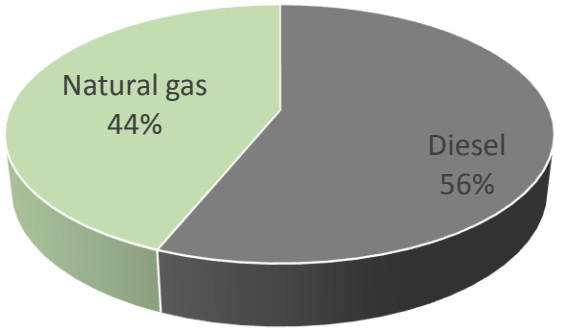


منبع: مریم نادری، وحید حسینی "پایش کیفیت سوخت بنزین و دیزل شهر تهران- سال های 1390 تا 1393"، گزارش فنی شرکت کنترل کیفیت هوا، شماره QM94/02/01/(U)/01– تیر 1394

Fleet Technology Diversity (Tehran case)

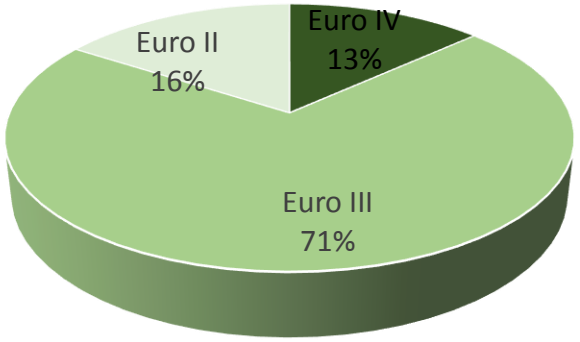
Tehran public bus fleet (municipality) 6554							
Governmental Sector				Private Sector			
2497				4057			
Diesel		Natural gas		Diesel		Natural gas	
1956		541		1723		2334	
BRTs	Ordinary	BRTs	Ordinary	BRTs	Ordinary	BRTs	Ordinary
1504	452	0	541	0	1723	0	2334

Fuel Classification



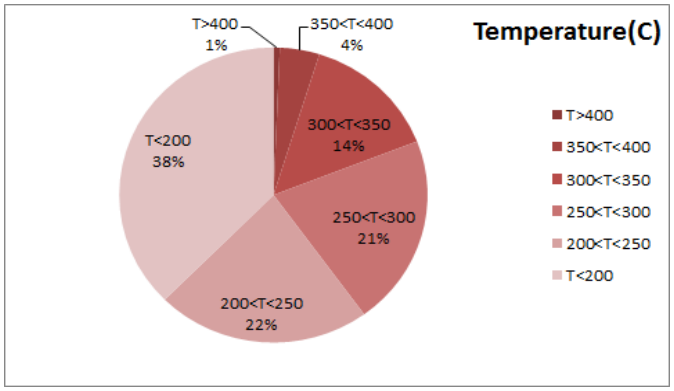
Tehran BRTs						
Average life	**Entrance year**	**Count**	**Double cabin**	**Single Cabin**	**Engine**	**Bus Type**
5 years	2009-2011	835	X		MAN Euro 3	King Long
5 years	2008-2011	200	X		MAN Euro 3	YOUNGMAN
1 year	2015	200	X		MAN Euro 4	Yutong
9 years	2004-2010	249		X	RENAULT Euro 2	SHAHAB
1 year	2014	20		X	RENAULT Euro 2	SHAHAB
–	–	1504	1235	269	–	Total

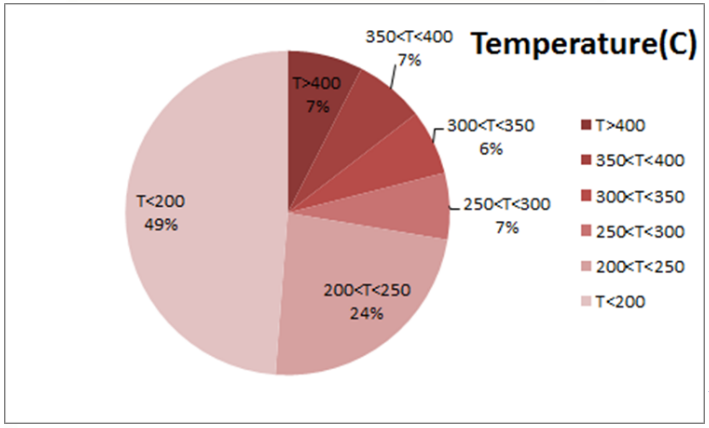
BRTs' Emission Standards



Different Routs (Tehran case)

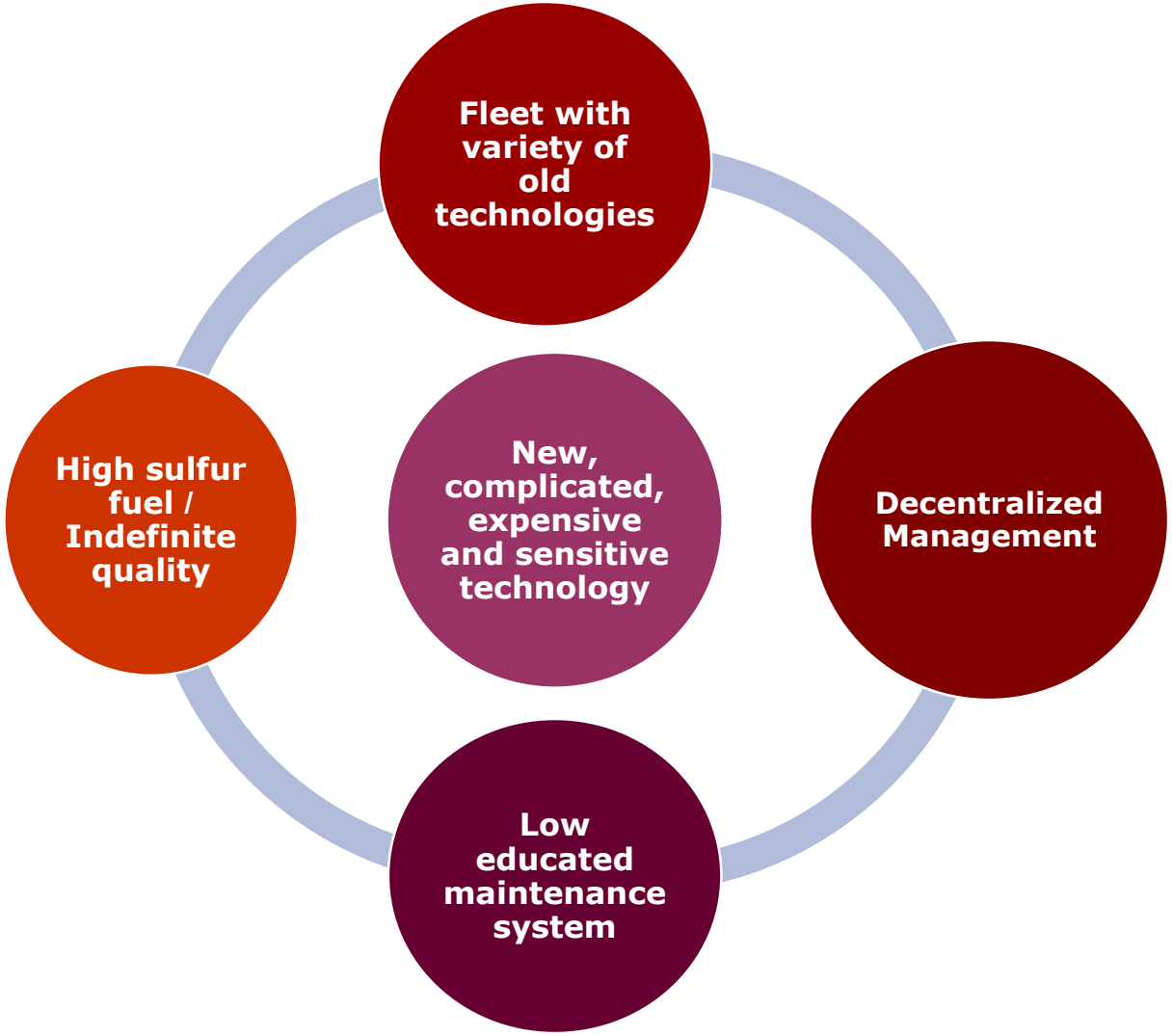
260 Lines





Line Number	Total Path Distance	First Terminal Name and Altitude	Second Terminal Name and Altitude	Path Average Slope
2	19 km	Western bus terminal – 1184.75 m above see level	Khavaran bus terminal – 1118.58 m above see level	0.19 Degrees
4	22.8 km	South bus terminal- 1108.22 m above see level	Park vey bus terminal- 1571.04 m above see level	1.16 Degrees
10	10.7 km	Western bus terminal – 1184.75 m above see level	Daneshgah square- 1601.14 m above see level	2.23 Degrees

DPF Retrofit Program Challenges



Experiences from Retrofit Activities in Tehran / Requirements

The Action

Fleet Documentation

- Routs specifications (slope, length, load, daily mileage, …)
- Engine specifications (model, emission level, aftertreatment, ..)
- Fleet age classification (<50k, <100k, <200k, …)
- Owner (Municipality, private)
- Daily and weekly regular check list (oil consumption, …)
- Maintenance system (organization, skill level, …)
- Normal oil and fuel type

Fuel and Oil Concerns

- Normal fuel type (sulfur fuel, …)
- Worse case fuel sulfur level and distribution regime
- Fuel distribution organization and related key people
- Availability of low sulfur fuel (< 50ppm)
- Possibility of dedicated fuel distribution system for retrofit program
- Availability and cost of suitable oil for DPF

Training Program

- Classification of stakeholders (drivers, Inspectors, maintenance technicians, workshop managers, …)
- Providing training materials in different levels and different scopes
- Train courses planning and implementation
- On-job training, Educational posters, …

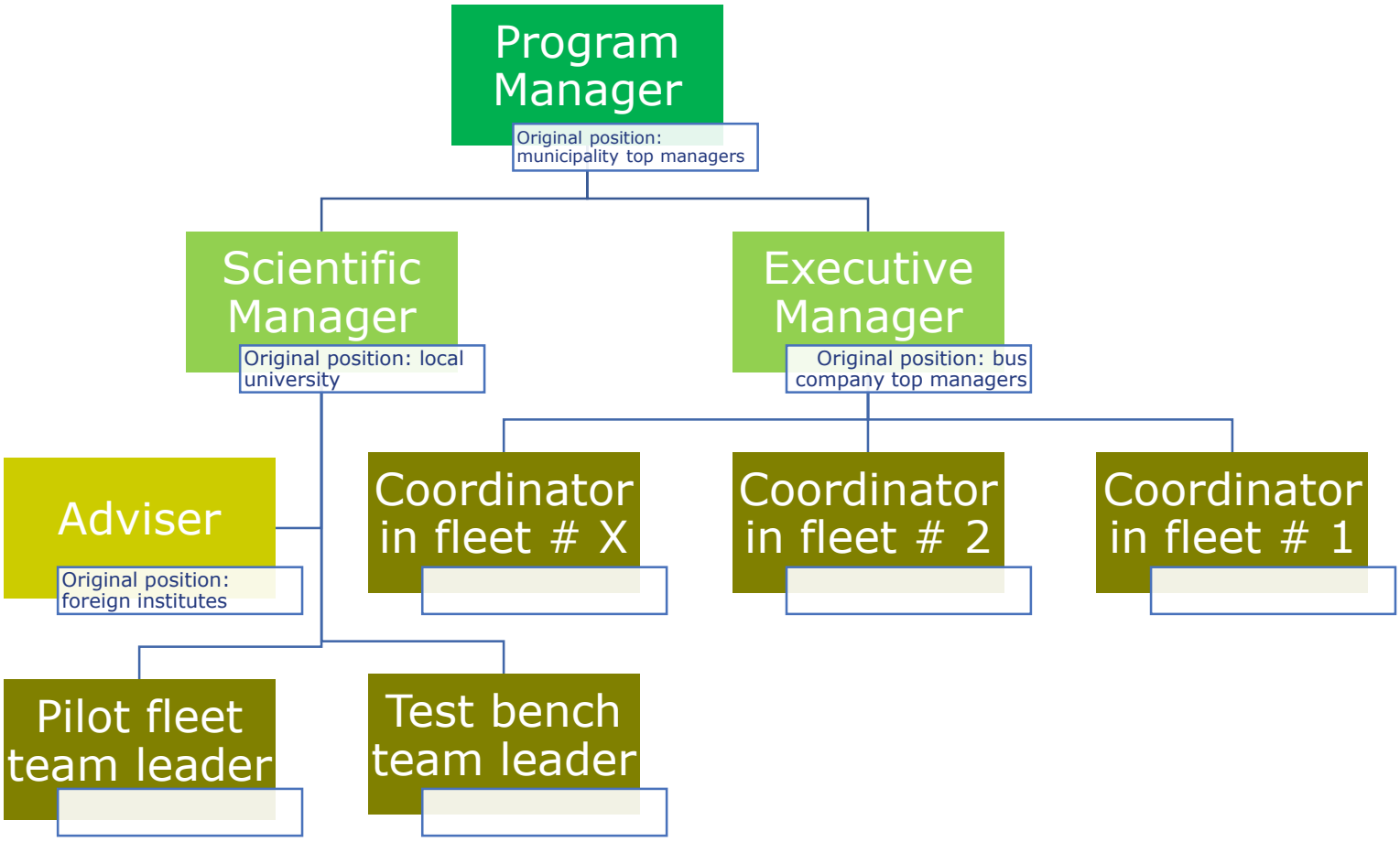
Engine and Pilot Fleet Testing

- Engine test planning
- Selecting different type of DPF technologies (low cost to expensive)
- Selecting proper engine model
- Engine testing with different fuels
- Installation accepted DPFs on pilot fleet
- Running and monitoring pilot fleet on real world

Project Leading

- DPF retrofit program is a complicated and science-based project
- Integration of well known foreign institutes, local universities and professional experts will reduce the risk of such project
- Municipality and bus company managers must believe and fully support the project

Project Organization



Project Planning

Advance planning

- Cost-Benefit assessment
- Budget providing
- Project organization
- Fleet documentation
- Project planning
- Adviser selecting
- Inviting approved suppliers to participate
- General training

Pilot tests

- Selecting reference engine
- Engine test planning and implementation
- Test results assessment and acceptable tech.
- Selecting pilot fleet
- Pilot fleet instrumentation and monitoring
- Sample DPF installation
- Pilot fleet running and monitoring
- Suppliers and technology rating
- Documentation and recording learning issues
- Training

First batch installation

- Selecting the most confident technology and supplier
- Installation a few hundreds DPFs
- Instrumentation all or most of buses with monitoring system
- Installation and maintenance of DPF by supplier
- Monitoring DPF performance by independent adviser
- On-job training of bus company personals
- Documentation and recording learning issues
- First batch assessment (challenges, deviations, cost, negative consequences, …)

Second batch installation

- Adding new supplier and new low cost tech.
- Installation hundreds or thousands DPFs
- Instrumentation a few buses with monitoring system
- Installation DPF by supplier
- DPF maintenance by bus company (after guarantee)

Experiences from Retrofit Activities in Tehran / Case Study

Fleet Documentation

Topics of Tehran Fleet Data Base

- Fleet organization
- Owner companies
- Routs data
- Maintenance terminals
- Operational terminals
- Buses' data base

Fleet Data Base

Tehran Bus United Company Organization

هیأت مدیره

Companies' Data Base

Company name	CEO	Operation routs	Number of diesel buses	Majarity engine brands
Tehran Bus United Company	Sanandagi	BRT (Line # 1 to # 10)	1956	MAN & Renault
Nedaye Beh Avaran	Karim Karami	3 and 4	382	Man
Faratarabar Mahdi	Mohsen Raeesi Mozd Abadi	Azadi-Hafte Tir, Rah Ahan-Hafte Tir, Meydan Emam-Ghods,...	300	Scania
Eimen Seir Hoveizeh	Mohammad Dazhmi Fard	Resalat-Meydan Ghods, Meydan Resalat-Meydan Zeinaldin, Moallem- Emam Khomeini,...	220	Akia 457
Taav				

Routs' Data Base

Line type	Line number	Start station	End station	Length(km)	Direction	Ave. slope(degree)	Number of stations (go&back)	Number of buses	Major bus types	Maintenance terminal	Operational terminal	Main operation company	Normal fueling station
BRT	2	Azadi bus Terminal	Khavaran bus Terminal	18/7	West to East	0/19	26	235	kinglong	Main Terminal	Main Terminal		Main Terminal
BRT	10	Azad University of north branch	Azadi bus Terminal	12	North to South	2/23	15	53	kinglong	Main Terminal	Main Terminal		Main Terminal
BRT	4	South bus Terminal	Afshar bus Terminal	21/5	North to South	1/16	24	100	kinglong	Main Terminal	Main Terminal	Nedaye Beh Avaran	Bokharaee

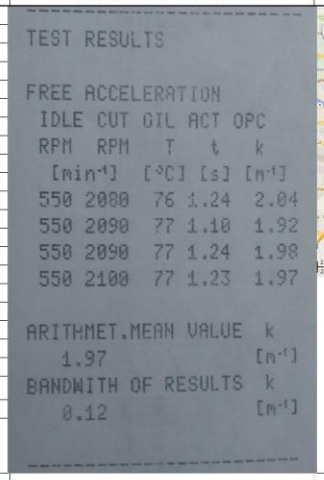
Vehicle Data Base

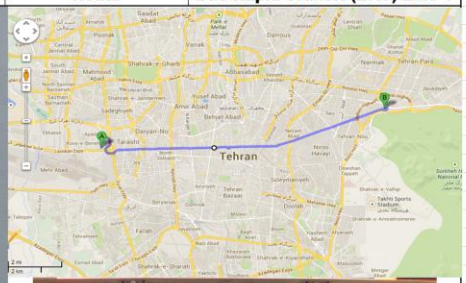
BUS REPORT - Excel

FILE | HOME | INSERT | PAGE LAYOUT | FORMULAS | DATA | REVIEW | VIEW

Q35

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Gerenal Information**		**Smoke Measurement**					**Route**	**Bus Rapid Transit (BRT) Line 1**				
2	Lisence Plate / Registration number	33453											
3	Mileage at the time of smoke measurement (km)	157193											
4	Bus type and Model	KINGLONG Articulated											
5	Production Date	2011											
6	Model	XMQ 6180G1											
7	Series No	AA800234											
8	Engine No	50428141192799											
9	VIN	LA6B1N1M8BB300564											
10	Weight on front axis (kg)	6000											
11	Weight on rear axis (kg)	10000											
12	Weight on middle axis (kg)	11500											
13	Total weight loaded (kg)	27500											
14	Maximum speed (km/h)	80											
15	Fuel tank capacity (lit)	250											
16	length (mm)	17900											
17	width (mm)	2550											
18	height (mm)	3150											
19	min height from ground (mm)	140											
20	min rotation radius (m)	12											
21													
22	**Engine Specs**												
23	Model	MAN D2066LOH12											
24	Type	6-Cyl, in-line, water-cooled, 4-stroke with turbocharger and intercooler											
25	Bore (mm)	128											
26	Stroke (mm)	155											
27	Displacement volume (mL)	11976											
28	Maximum rated brake power (hp)	350											
29	Maximum rated torque (Nm) @1000-1400 rpm	1750											
30	idle speed (rpm)	550±50											
31	Maximum rated speed at idle (rpm)_	2200											
32	Compression ratio	19.0±0.5:1											
33	Lubricating oil	Lai Ke Cl-4/SL 15W/40											
34													





A Western Bus Terminal of Tehran	B Tehranpars Bus Terminal
total distance (Km)	19

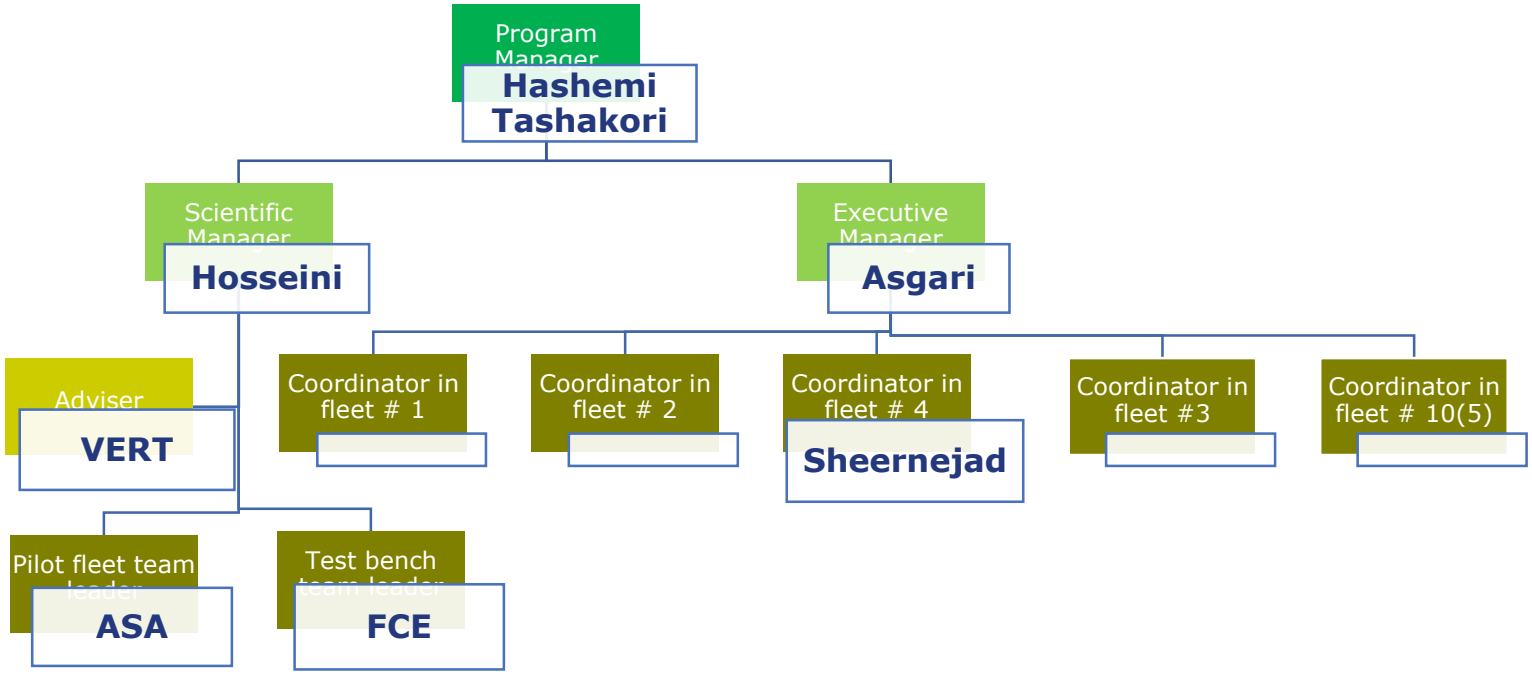
COVER | 32923 | 32895 | 32938 | 32914 | **33453** | 33469 | 33457 | 85156

READY

Experiences from Retrofit Activities in Tehran / Case Study

Project Organization

Tehran DPF Project Organization



Experiences from Retrofit Activities in Tehran / Case Study

Project Planning

Tehran DPF Project Progress

Initial Planning (not available)

Actual Progress

Year	2013				2014				2015				2016
Quarter #	1	2	3	4	1	2	3	4	1	2	3	4	1

- AQCC and VERT initial meeting
- National DPF legislation approved by cabinet
- First filter installation on the bus
- Core of 1th installed DPF was cleaned after 36000 km for the first time
- Program was approved at Tehran city council for 200, 600 and 2000 buses
- Testing of first filter in the engine test bench
- Running 8 buses with DPF's of 4 suppliers, 17 buses with data logger, maximum operated DPF: 78000 km/475 days/one cleaning
- First exhaust data collection of the buses
- First bus instrumented with data logger
- Engine tests were completed for 7 filters, 6th bus filter installation

Experiences from Retrofit Activities in Tehran / Case Study

Test Bench Activities

General Information

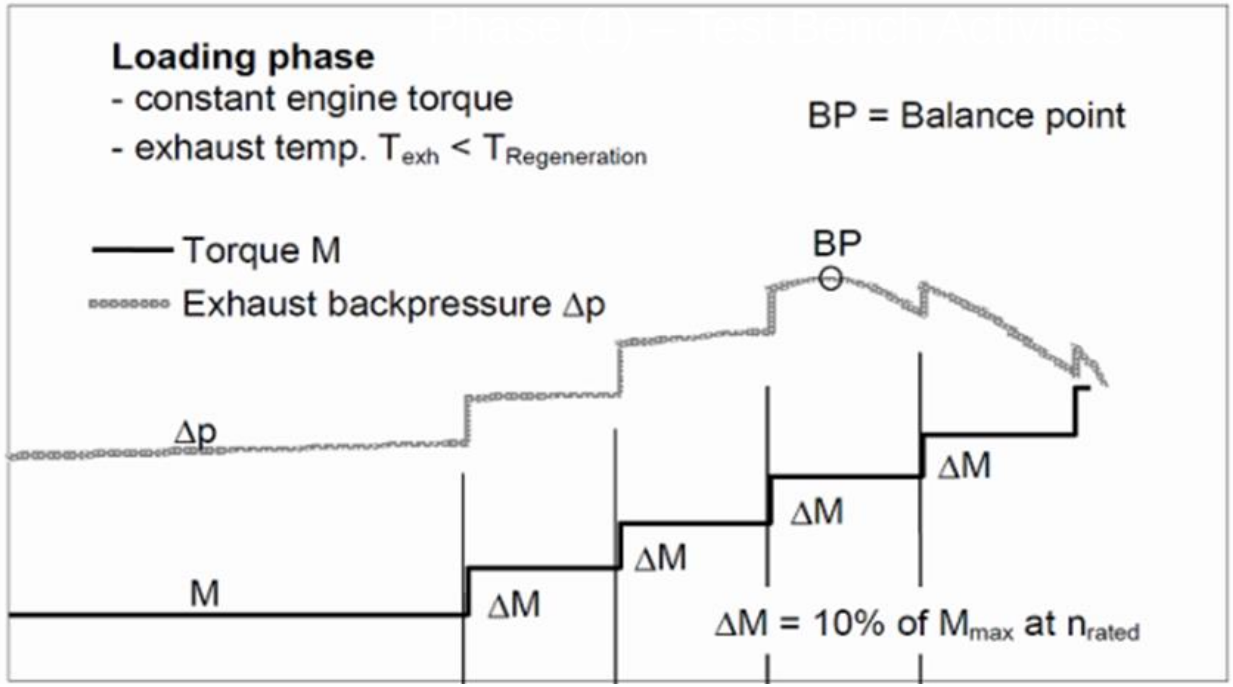
Phase 1 – Laboratory Tests	
Start Date	July 2014
Test Site	IDEM Company's engine test bench
Taskmaster	AQCC
Executer	FCE (Sharif U of Tech)
Supervisor	VERT
Participated DPF Companies	HJS- Dinex- Puritech- Tehag- Huss- Hug…

Tested Engine Type

Manufacturer / type	IDEM(OM457)
Serial number / year of manufacture / operating hours	(AENR)P090737/2014/10
Emission legislation level	EU(II)
Cylinder number and configuration	6 inline
Bore x stroke / overall displacement	128 x 155 [mm] / 12 [dm^3]
Compression ratio	17.25
Cooling medium (air, water, etc.)	Water
Combustion process	direct injection
Supercharging / Charge air cooling / Charge pressure max.	Turbocharger/intercooler/
Exhaust aftertreatment measures to reduce emissions	No
EGR	No
Rated power / Rated speed	220 [kW] @ 2000 [min^{-1}]
Max.Torque @ RPM	1250 [Nm] @ 1100 [min^{-1}]
Max exhaust temperature downstream TC @ nominal RPM	500° C @ 1000 [min^{-1}] /
Low idle speed / high idle speed	600±50 [min^{-1}]; 2100 [min^{-1}]

Test Procedure (VTF1)

- Engine baseline test (4PTS without DPF)
- DPF efficiency and operation test (4PTS with DPF)
- Soot loading
- Regeneration test



Sulfur Content of Used Fuels and Related Test Results

	Low Sulfur	Medium sulfur	High sulfur
Sulfur level	48-50 ppm	230-250 ppm	7000-7700 ppm

DPF producer company	DPF type	VTF1 (Low Sulfur)	VTF1 (Medium Sulfur)	VTF1 (High Sulfur)
A	Active - Electrical heater	Not tested	Pass	Pass
A	Passive - CRT	Incomplete	Failed	Not tested
B	Passive - FBC	Not tested	Pass	Pass
C	Passive - FBC	Not tested	Pass	Pass
D	Passive - CDPF	Not tested	Pass	Not tested
E	Passive - CRT	Not tested	Failed	Not tested
F	Active - Diesel burner	Not tested	Failed	Not tested
F	Active - Post injection	Not tested	Waiting for VERT and AQCC	Waiting for VERT and AQCC

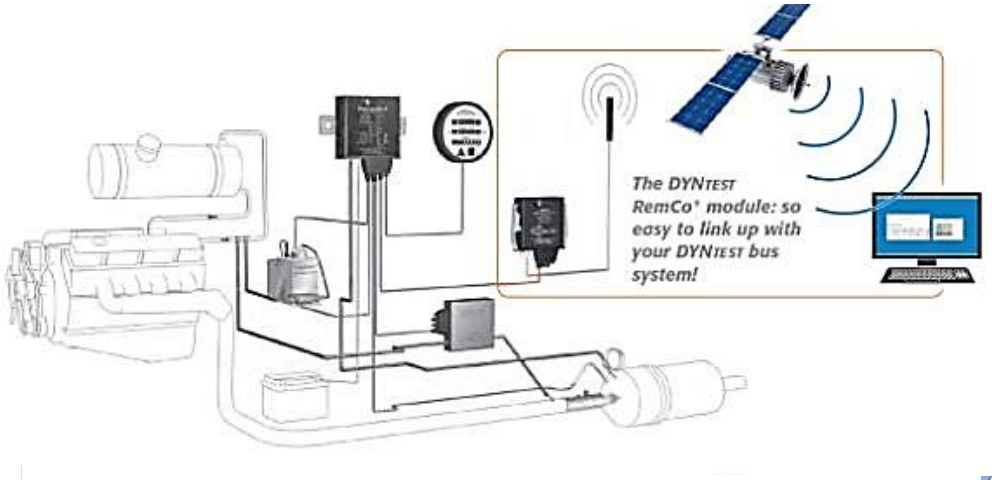
Experiences from Retrofit Activities in Tehran / Case Study

Pilot Fleet Monitoring Before DPF Installation

Tools of Monitoring

- Periodic K-value and emission measurement
- On-line data logger
- Daily check list
- Regular data processing and reporting

Used equipment-data logger

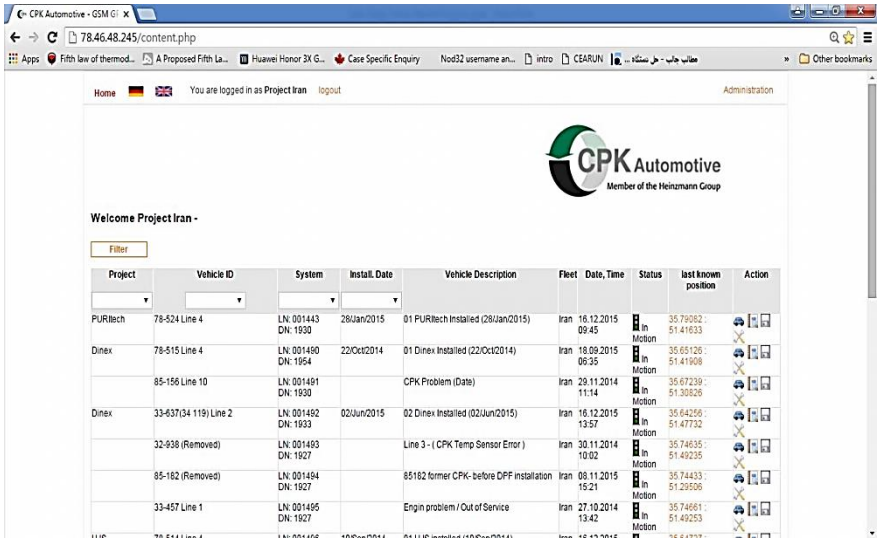


Some of Important Features
Online information sending
GPS reports
Programmable SMS sending option
Recording temperature, pressure and operation parameters data

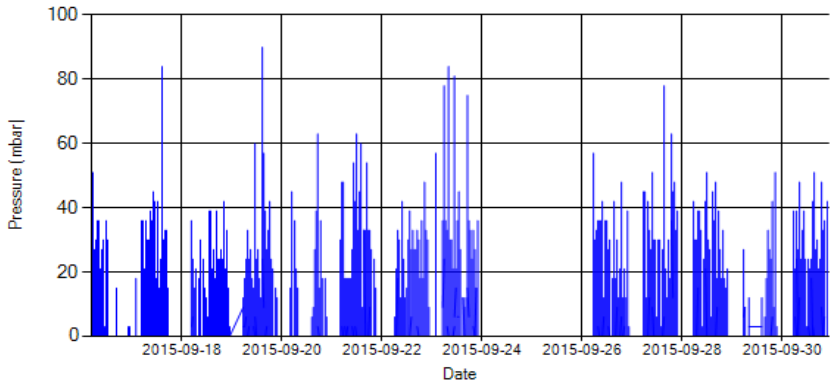
GPS Reports for 001443

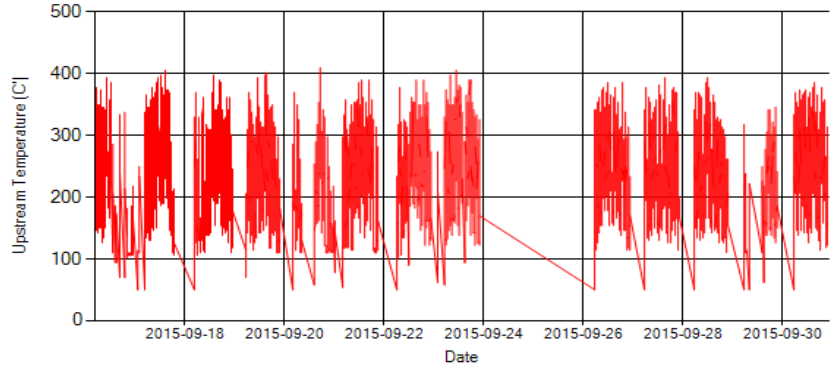
No.	Start Time	Stop Time	Duration	
1	16.12.2015 03:07	16.12.2015 09:45	6h :39 min.	DETAILS
2	14.12.2015 05:36	16.12.2015 01:26	43h :50 min.	DETAILS
3	12.12.2015 23:55	13.12.2015 23:17	23h :22 min.	DETAILS
4	12.12.2015 10:13	12.12.2015 10:33	0h :20 min.	DETAILS
5	12.12.2015 07:31	12.12.2015 07:46	0h :15 min.	DETAILS
6	11.12.2015 20:16	12.12.2015 06:07	9h :51 min.	DETAILS
7	11.12.2015 08:40	11.12.2015 09:03	0h :23 min.	DETAILS
8	11.12.2015 08:31	11.12.2015 08:33	0h :2 min.	DETAILS
9	11.12.2015 06:37	11.12.2015 06:42	0h :5 min.	DETAILS
11	10.12.2015 09:19	10.12.2015 09:25	0h :5 min.	DETAILS

	Date, Time	Speed (mph)	Direction (Degree)	Altitude (ft)
Start:	16.12.2015 03:07	0	130	3609
Stop:	16.12.2015 09:45	0 ; 0	82	1593 ; 5226



Sample Collected Information





Document #:ABL2014DPF009 version: 01 Page:4 of ..		Daily check	
1	driver name		
2	mileage (km)	130247	
3	fueling	Yes ☒	No ☐
	if yes then fueling station:	fuel amount (lit): 84	
4			
5			
6			
7			
8			

Document #:ABL2014DPF009 version: 01 Page:4 of ..		Daily check	
1	driver name		
2	mileage (km)	130435	
3	fueling	Yes ☒	No ☐
	if yes then fueling station:	fuel amount (lit): 145	
4			
5			
6			
7			
8			

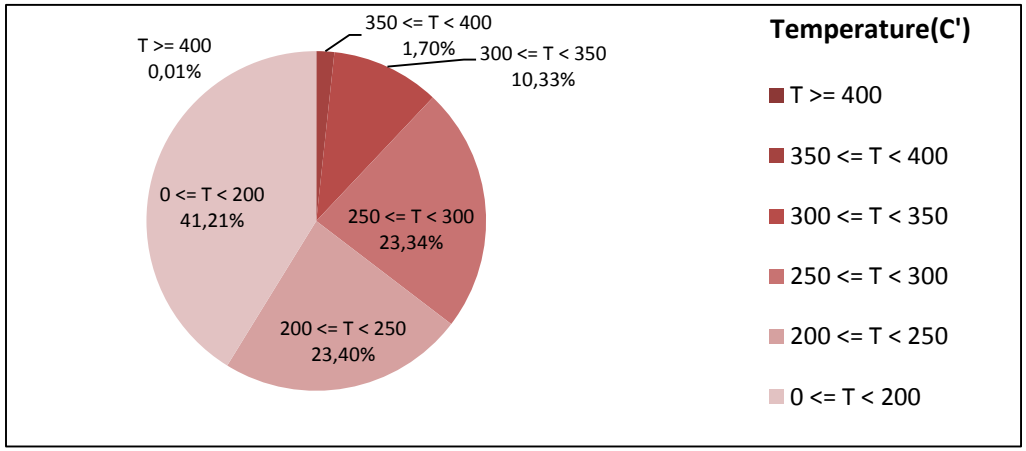
Document #:ABL2014DPF009 version: 01 Page:4 of ..		Daily check	
1	driver name		
2	mileage (km)	130638	
3	fueling	Yes ☒	No ☐
	if yes then fueling station:	fuel amount (lit): 160	
4	adding additive	Yes ☐	No ☒
	if yes then additive type:	additive amount (lit):	
5	adding engine oil	Yes ☐	No ☒
	if yes then oil type:	oil amount (lit):	
6	engine malfunction	Yes ☐	No ☒
	if yes please more description:		
7	maintenance	Yes ☐	No ☒
	if yes please more description:		
8	data logging system	Ok ☒	Nok ☐
	if nok please more description:		
	Comments:		
	Date:16/10/2014	Time:	Site: 2	Name: Asem	Signature:

Sample Parts of Technical Reports

System and path Overall information

Vehicle plate number	33637 (34119)
CPK data logger number	LN: 001492, DN: 1933, Sim +989210000000
Bus line	Number 2 (west to east bus line)
Bus Terminals	Khavaran Bus Terminal - Western Bus Terminal
Total path distance	19 km
Report period	16/Sep/2014 – 30/Sep/2014
K value	2.00 [1/m]

Temperature distribution over the working hours



Supplementary information

Bus mileage over the period	2190 km
Working days over the period	13 days
Stop days	2 days
Data logger working days	13 days
Working hours over the period	200 hours 23 minutes
Average working hours per day (including stop days)	13 hours 21 minutes
Bus average speed	10.93 km/hr
Idle speed time to all working time ration	57.04 %
Total Bus fuel consumption over the period	1440 lit
Fuel consumption per hour	7.19 lit/hr
Average fuel consumption	0.66 lit/km

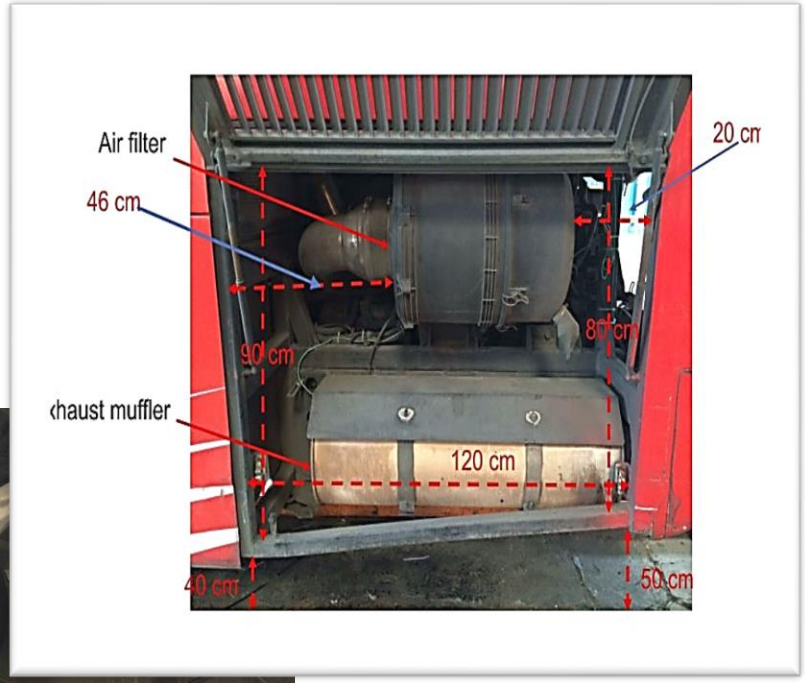
Overall Status of Pilot Fleet Instrumentation

No.	Vehicle ID	Operating Line	Vehicle Brand/ Model	Engine Type	Year Mileage (km)	Emission Standard	Last measured Opacity K (1/m)	Data logger ID (LN)
1	32938	Line 3	KINGLONG XMQ 6180G1	MAN D2066LOH12	2008 -	Euro III	1.36	Current Status: NO CPK
2	33469	Line 1	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 271990	Euro III	1.24	001499
3	85182	Line 10	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 216537	Euro III	1.84	Current CPK 001502
4	78514	Line 4	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 290687	Euro III	1.60	001496
5	78515	Line 4	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 322060	Euro III	1.40	001490
6	33637	Line 3	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 181102	Euro III	2.00	001492
7	33592	Line 2	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 -	Euro III	1.28	001497
8	32923	Line 3	KINGLONG XMQ 6180G1	MAN D2066LOH12	2008 -	Euro III	2.53	001506
9	32914	Line 3	KINGLONG XMQ 6180G1	MAN D2066LOH12	2008 -	Euro III	2.14	001501
10	33453	Line 2	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 -	Euro III	1.97	001522
11	33457	Line 1	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 183983	Euro III	1.37	001495
12	85156	Line 10	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 289225	Euro III	1.55	001491
13	85476	Line 10	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 251310	Euro III	1.84	001508
14	85423	Line 4	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 319651	Euro III	1.78	001505
15	33572	Line 2	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 178966	Euro III	1.80	001521
16	33599	Line 2	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 -	Euro III	2.02	001520
17	78524	Line 4	KINGLONG XMQ 6180G1	MAN D2066LOH12	2011 278973	Euro III	1.90	001443

Experiences from Retrofit Activities in Tehran / Case Study

Sample DPFs Installation

Packaging Investigation and K-value Measurement



K-value measurement


OPACITY
max. .50

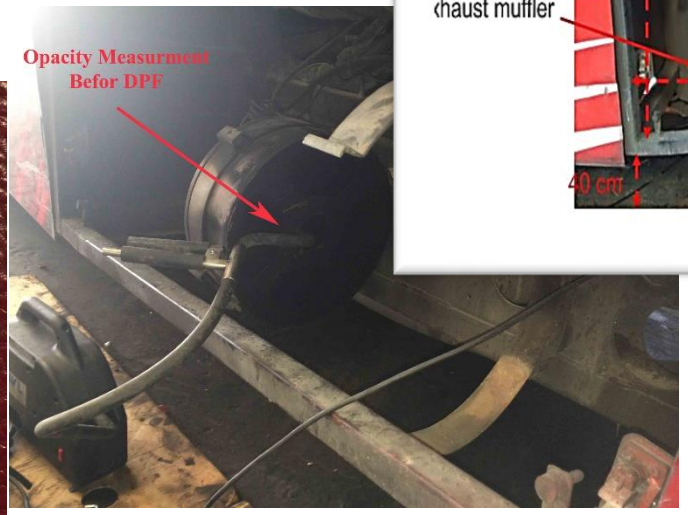
TEST RESULTS

FREE ACCELERATION

IDLE	CUT	OIL	ACT	OPC
RPM	RPM	T	t	k
[min⁻¹]		[°C]	[s]	[m⁻¹]
550	2120#	80	1.37	1.01
550	2110#	80	1.46	1.00
550	2110#	80	1.50	0.99
550	2120#	80	1.46	1.05

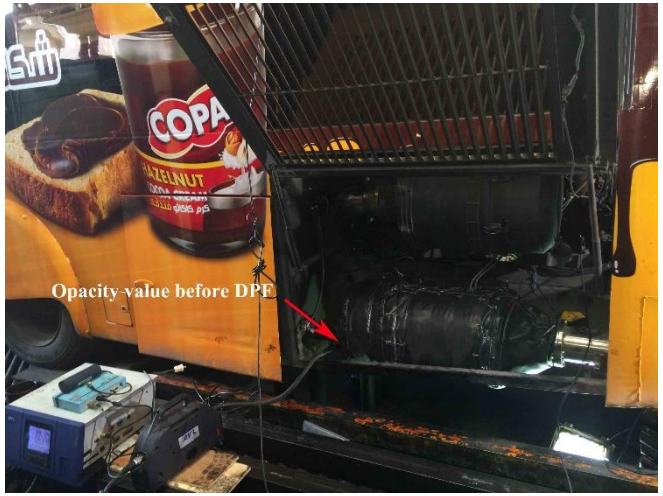
ARITHMET.MEAN VALUE k
1.01 [m⁻¹]
BANDWITH OF RESULTS k
0.06 [m⁻¹]

TEST RESULT:



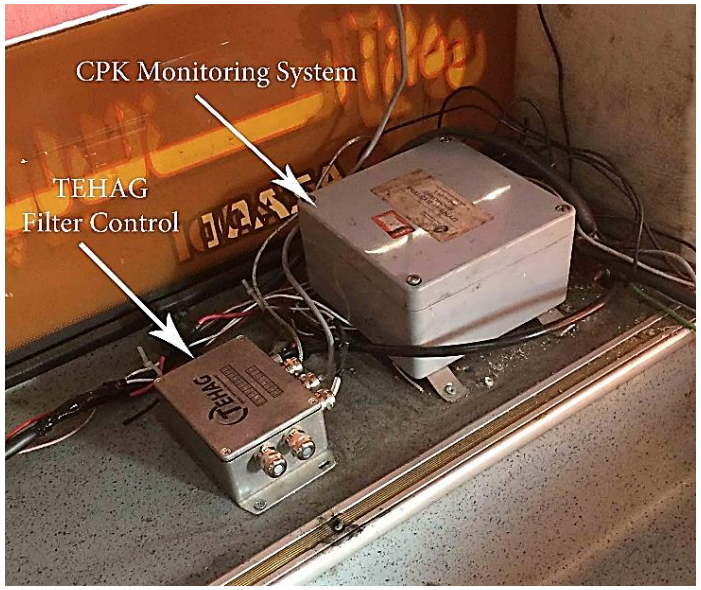
Sample DPFs Installation-flanges modification

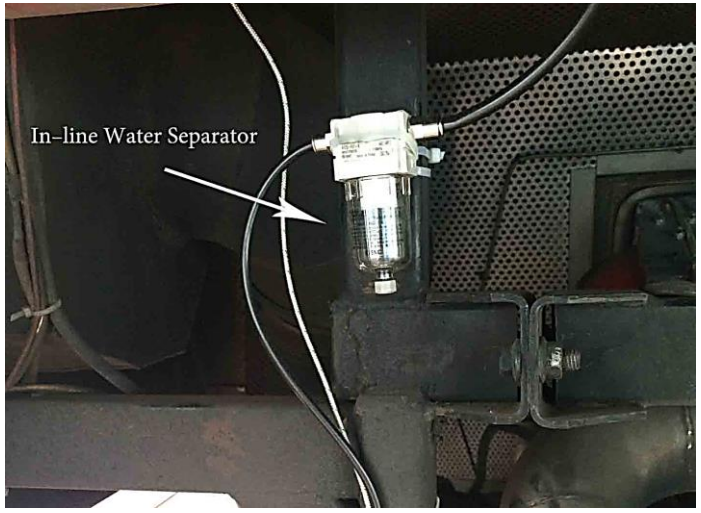
Sample DPFs Installation

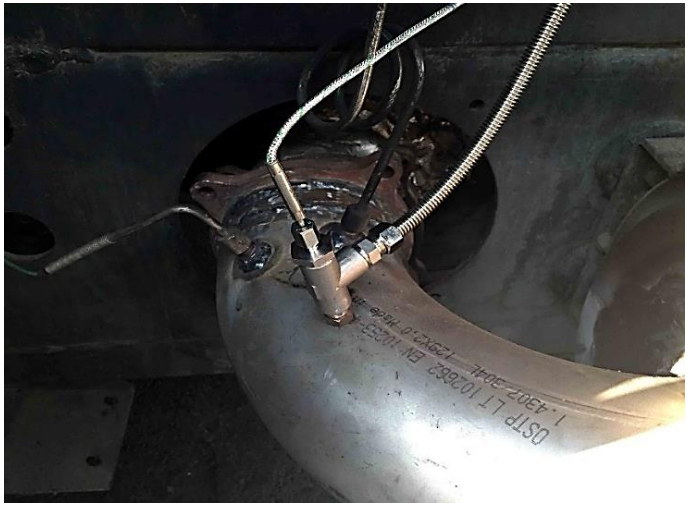


Sample DPFs Installation - Isolation and Additive system Installation

Sample DPFs Installation-setting electrical and monitoring system







Overall Status of DPFs Installation

DPF installation date	DPF producer company	DPF technology	Vehicle ID	Bus operated Line	Bus mileage until DPF installation (km)	K-value measurement (installation time)	
						B-DPF	A-DPF
10/Sep/2014	B	Passive system + FBC	78514	Line 4	229689	1.80	0.02
22/Oct/2014	A	Passive system + FBC	78515	Line 4	272444	2.00	0.04
28/Jan/2015	C	Passive system + FBC	78524	Line 4	239626	1.70	0.02
19/Feb/2015	B	Active system + FBC	85423	Line 4	280412	1.10	0.02
19/Feb/2015	B	Active system + FBC	33572	Line 2	142717	1.24	0.04
23/Feb/2015	B	Active system + FBC	85476	Line 10	212093	1.60	0.01
02/Jun/2015	A	Passive system + FBC	33637	Line 2	160695	2.00	0.02
24/Sep/2015	D	CDPF (Catalyzed DPF)	85182	Line 10	211553	1.76	0.00

Experiences from Retrofit Activities in Tehran / Case Study

Pilot Fleet Running and Monitoring

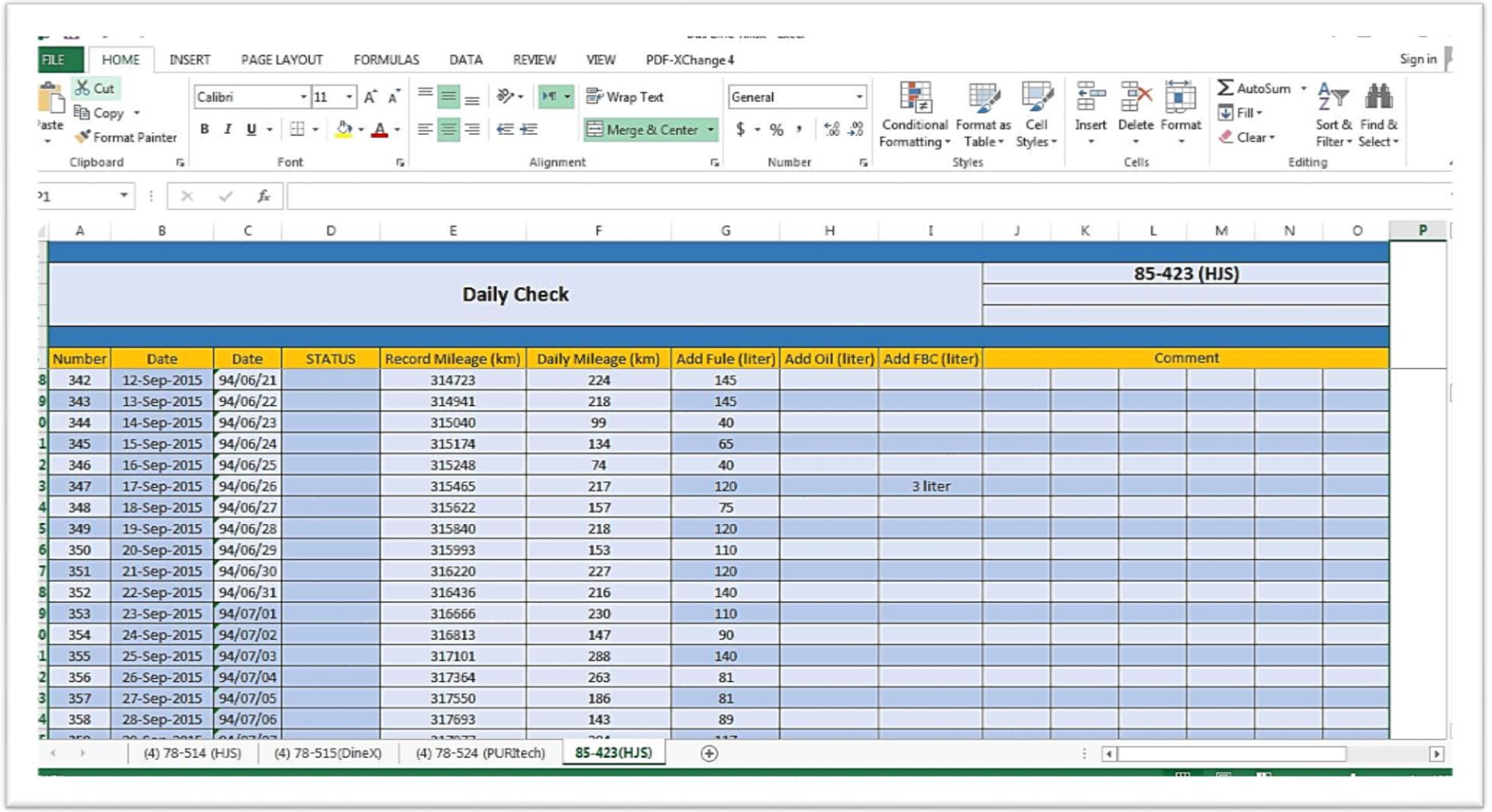
Pilot Fleet Monitoring

- On-line data logging of engine operational parameters

(Exhaust gas temperature – Backpressure – Engine rotational speed / Location & Time)

- Daily fuel consumption
- Additive consumption
- K-value measurement
- Recording daily mileage, oil consumption and …
- Periodic Fuel and oil quality analysis
- Regular visual inspection

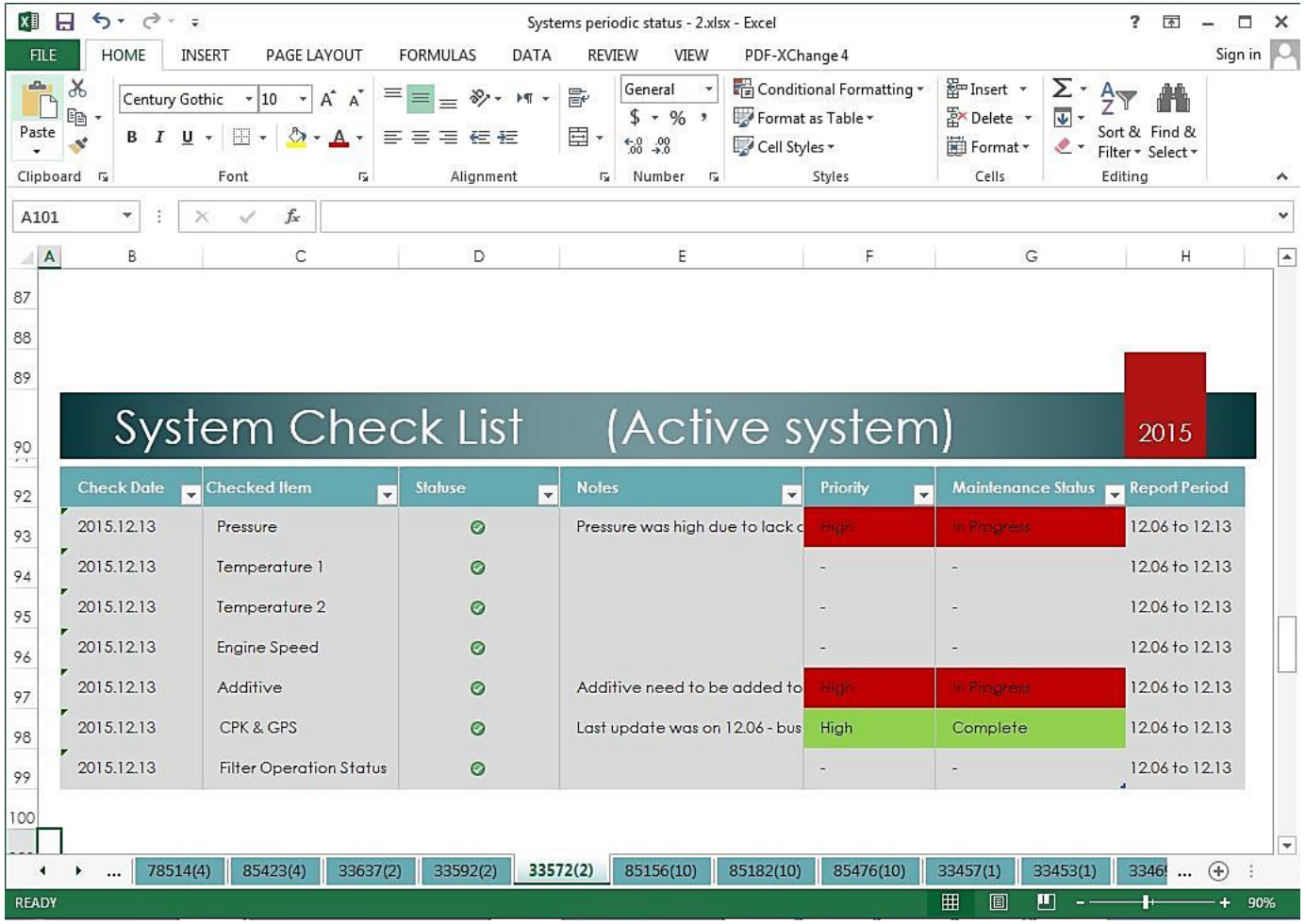
Daily Check List (mileage, fuel, additive, …)



Daily Check									85-423 (HJS)					
Number	Date	Date	STATUS	Record Mileage (km)	Daily Mileage (km)	Add Fule (liter)	Add Oil (liter)	Add FBC (liter)	Comment					
342	12-Sep-2015	94/06/21		314723	224	145								
343	13-Sep-2015	94/06/22		314941	218	145								
344	14-Sep-2015	94/06/23		315040	99	40								
345	15-Sep-2015	94/06/24		315174	134	65								
346	16-Sep-2015	94/06/25		315248	74	40								
347	17-Sep-2015	94/06/26		315465	217	120		3 liter						
348	18-Sep-2015	94/06/27		315622	157	75								
349	19-Sep-2015	94/06/28		315840	218	120								
350	20-Sep-2015	94/06/29		315993	153	110								
351	21-Sep-2015	94/06/30		316220	227	120								
352	22-Sep-2015	94/06/31		316436	216	140								
353	23-Sep-2015	94/07/01		316666	230	110								
354	24-Sep-2015	94/07/02		316813	147	90								
355	25-Sep-2015	94/07/03		317101	288	140								
356	26-Sep-2015	94/07/04		317364	263	81								
357	27-Sep-2015	94/07/05		317550	186	81								
358	28-Sep-2015	94/07/06		317693	143	89								

Daily Report (daily check list + on-line data logger)

- Daily DPFs' operation check by analyzing installed data loggers' data
- Periodic recording DPFs' status in the created data base



Check List of System Diagnostic and Troubleshooting

- On time problem detection and maintenance
  - ✓ Preparing System check list worksheet after analyzing data for visiting systems
  - ✓ Worksheets were filled up by ASA's technicians after visiting systems and troubleshooting

ASA
AZMOON SANAT ARVIN

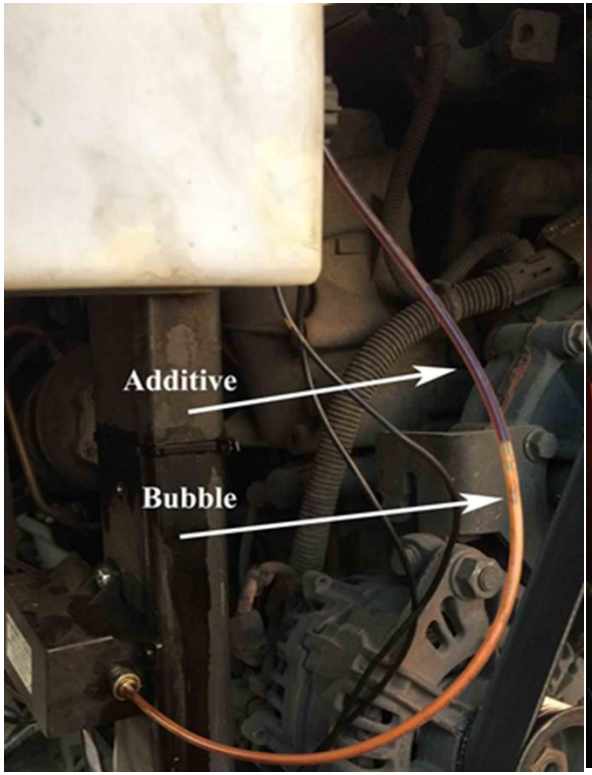
SYSTEM CHECK LIST

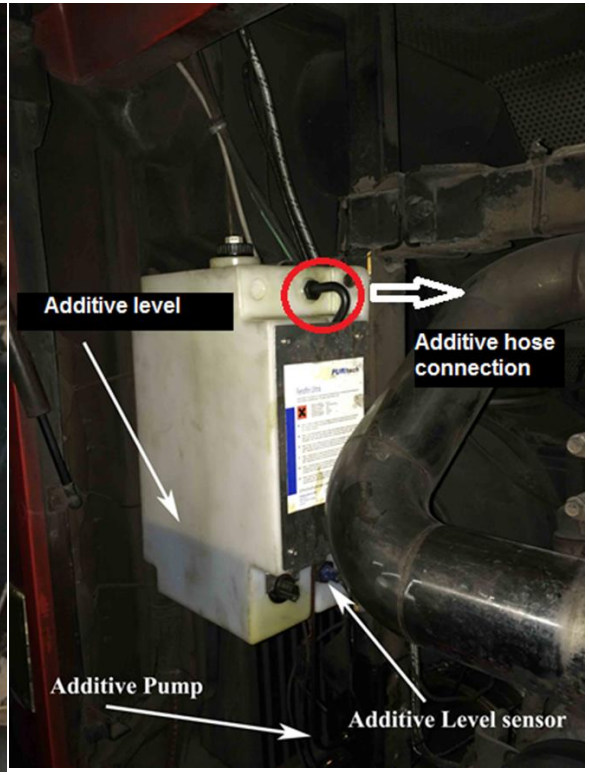
Vehicle Number:		Check Date:			DPF Company:
Section	**Items**	**OK**	**Not OK**	**Problem Specification**	**Comments/Changes**
CPK Section	Pressure Sensor	☒	☐		
	Temperature 1 Sensor	☒	☐		
	Temperature 2 Sensor	☐	☒		
	Engine Speed Sensor	☒	☐		
	CPK and GPS Updates	☒	☐		
	Working Hours (CPK and GPS matching)	☒	☒		
DPF Section	Filter Operation Status (cleaning necessity)	☒	☐		
	Additive Status	Current Value			Added Value
	K Values	Before DPF			After DPF
Bus Section	Bus Mileage				
	Other Maintenance Services				
Visual Section	Instruments Looseness	☐	☐		
	Additive Tank's Leakage	☐	☐		
	DPF Insulation	☐	☐		
	CPK Cleanliness	☐	☐		
	HMI	☐	☐		

DPFs' ECU Periodic Checking for Problem Detection

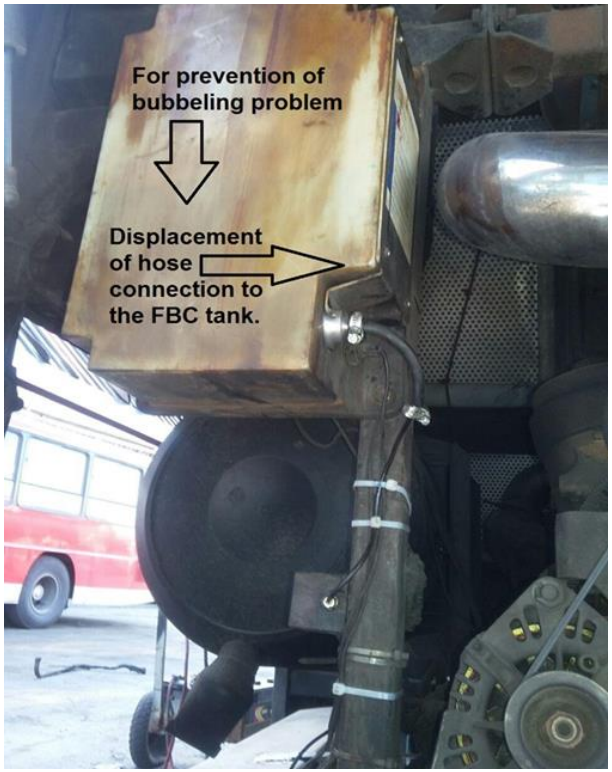
Checking Hardware Systems – system modification

Additive system problem





Problem solving

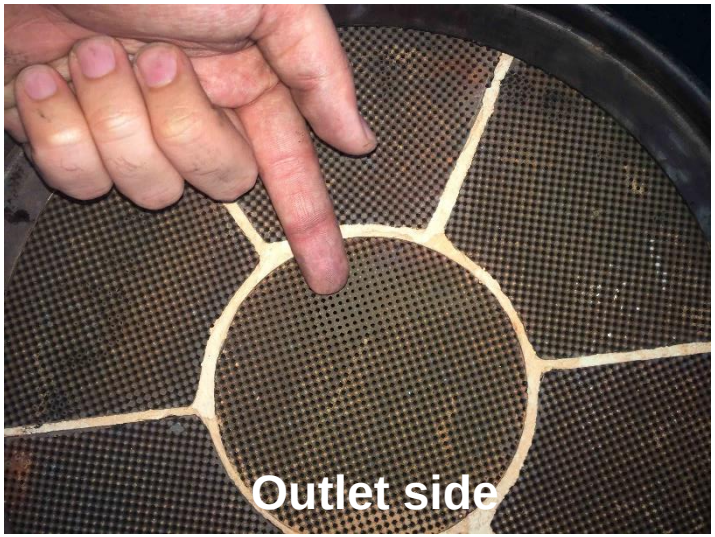


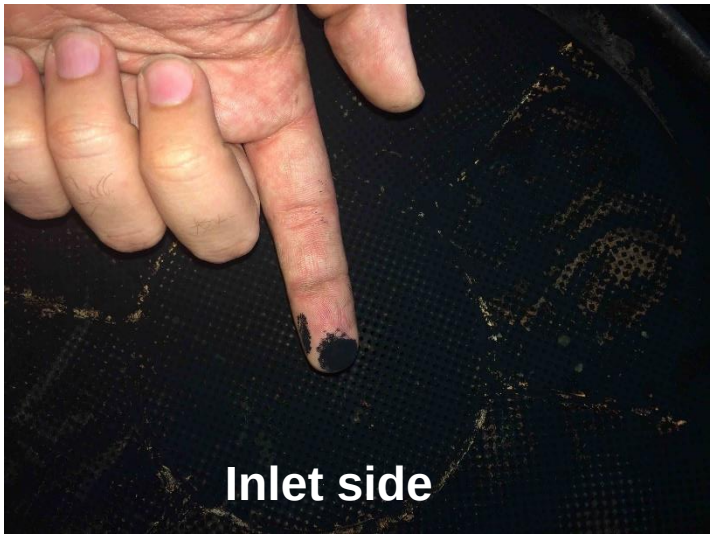
Checking Hardware Systems – system modification

Isolation system problem

Problem solving
Designing Special Heat Shield

Sample Filter After Six Months Operation





DPF Cleaning

Sample Fuel and Oil Specifications Measurement

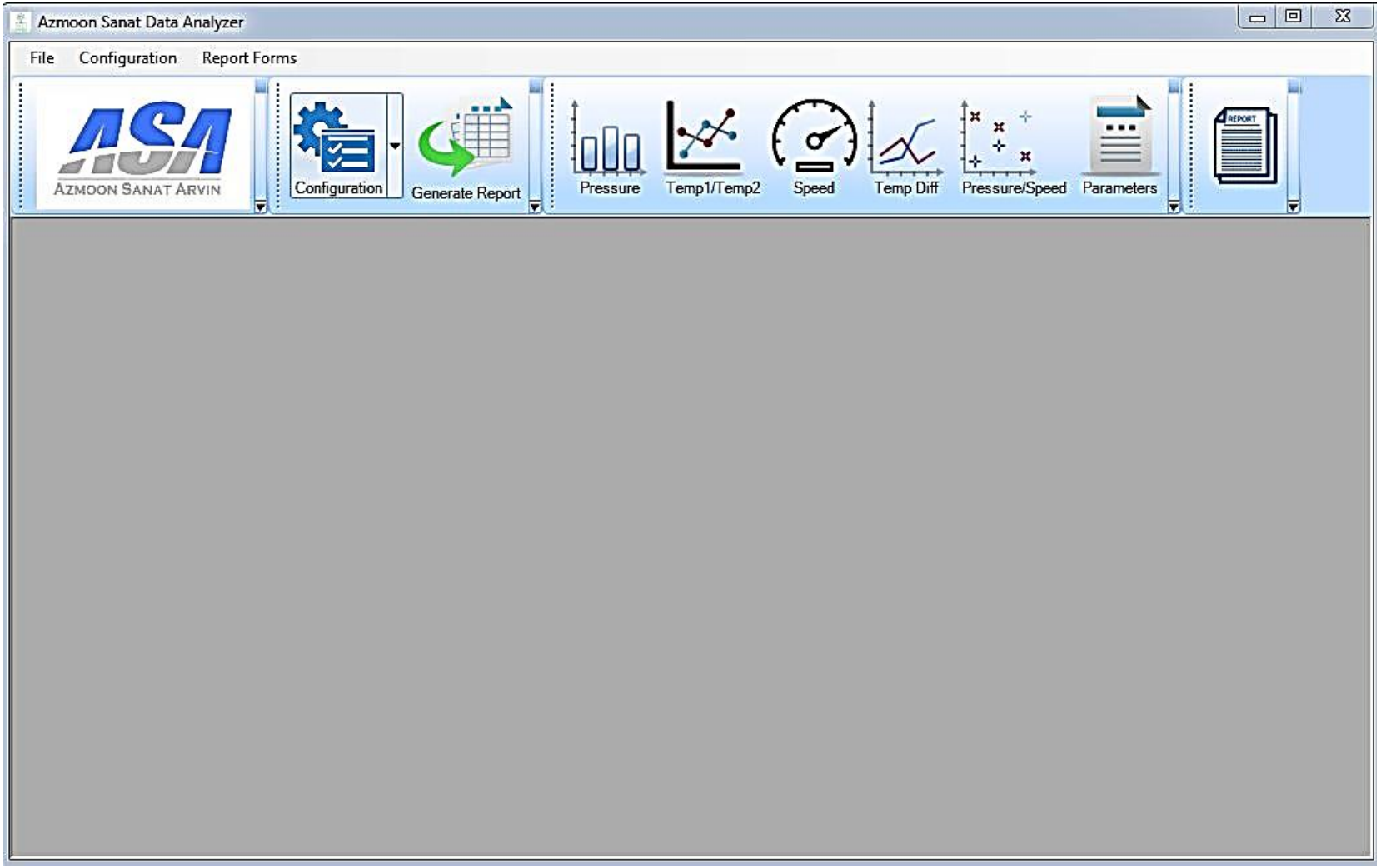
Low sulfur fuel for public bus transportation			
Fuel Station	Measured Season	Sulfur Content (ppm)	Cetane Number
Tehran- zone 2 (moshirie)	Spring	40.7	54.6
Tehran- zone 2 (moshirie)	Summer	40.8	-
Tehran- zone 2 (moshirie)	Fall	51.2	52.7
Tehran- zone 2 (moshirie)	Winter	78	-

Test Name: Oil Sulfated Ash-wt%		
Test Method: ASTM D874		
Vehicle ID: 78514		
Sample #	**Date**	**Result**
1	2014-Nov.	2.29
2	2014-Dec.	2.3
3	2015-Jan.	2.31

Experiences from Retrofit Activities in Tehran / Case Study

Project Documentation and Data Management

ASA Data Analyzer (Evaluating engine operational parameters)



ASA Data Analyzer's Feature

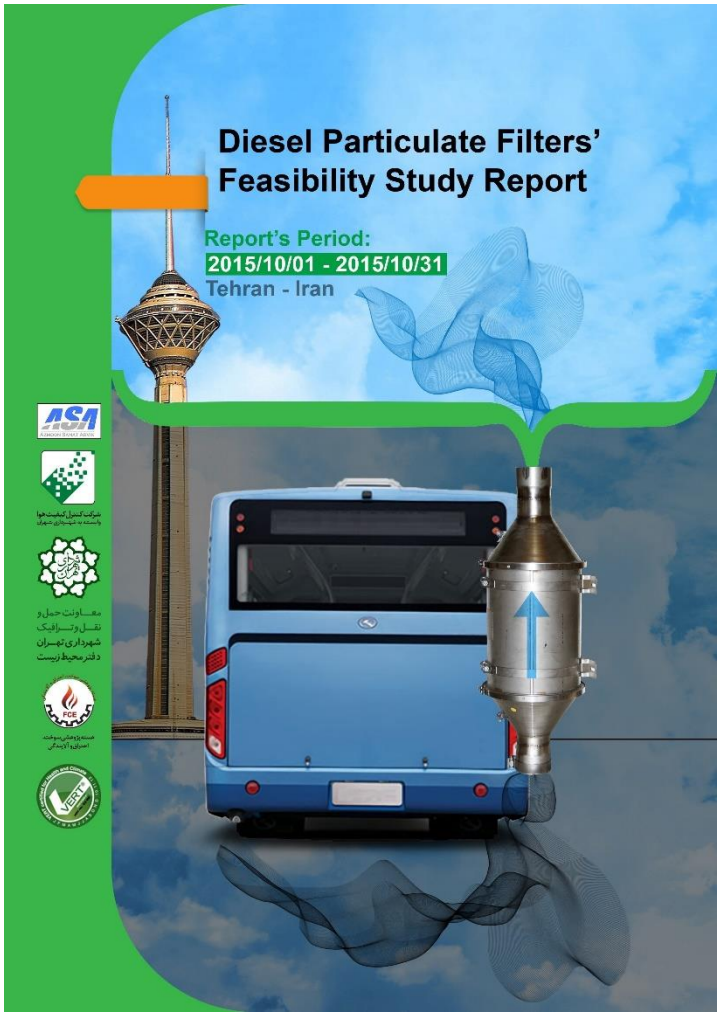
- Analytical charts for exhaust gas temperature
- Analytical charts for backpressure
- Analytical charts for rotational engine speed
- Calculating vehicle working hours
- Calculating idle working
- Fuel, additive, oil consumption
- Providing complete report as word file

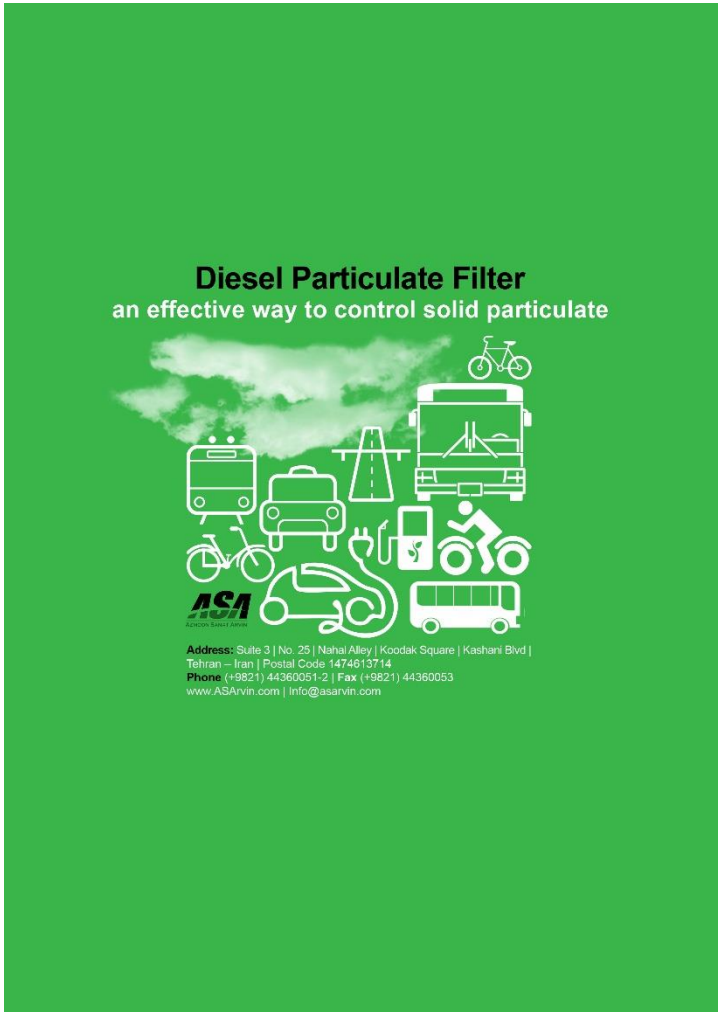
(all above-mentioned information)

Video (hyperlink)

Regular Monthly Reports

- Collecting DPFs' detailed information in the monthly reports

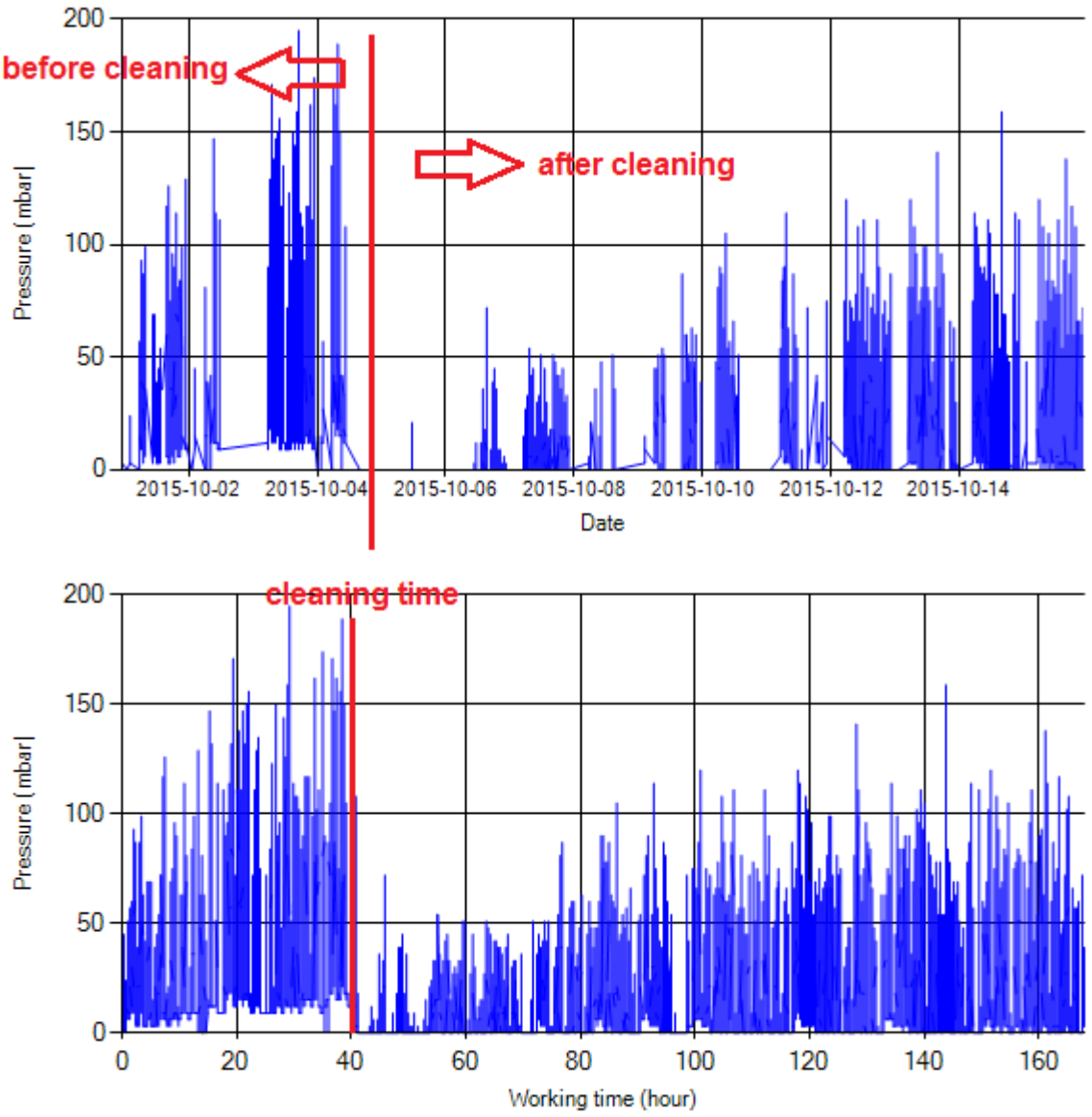




Sample of Decision Making Based on Back Pressure Analysis

- Observing High back-pressure
- Checking DPF system (Cleaning needed)

- Normal back-pressure (shows cleaning was efficient)



Sample DPFs Rating on Monthly Report

DPF Code	Operation Status
	Sep/01/2015 - Sep/15/2015
01	Excellent
02	Excellent
03	Good
04	Good
05	Good
06	Excellent
07	Good
08	Maintenance required

Operation Status	Description
Excellent	Pressure above 200 mbar<0.1% ($P200{\sim}0$)
Good	$0.1\% \leq P200 \leq 3\%$
Maintenance required	$P200 > 3\%$ or DPF system blocking
Failed	DPF defect, black smoke, holes in the filter element
NO DPF	DPF was removed for cleaning or other issues

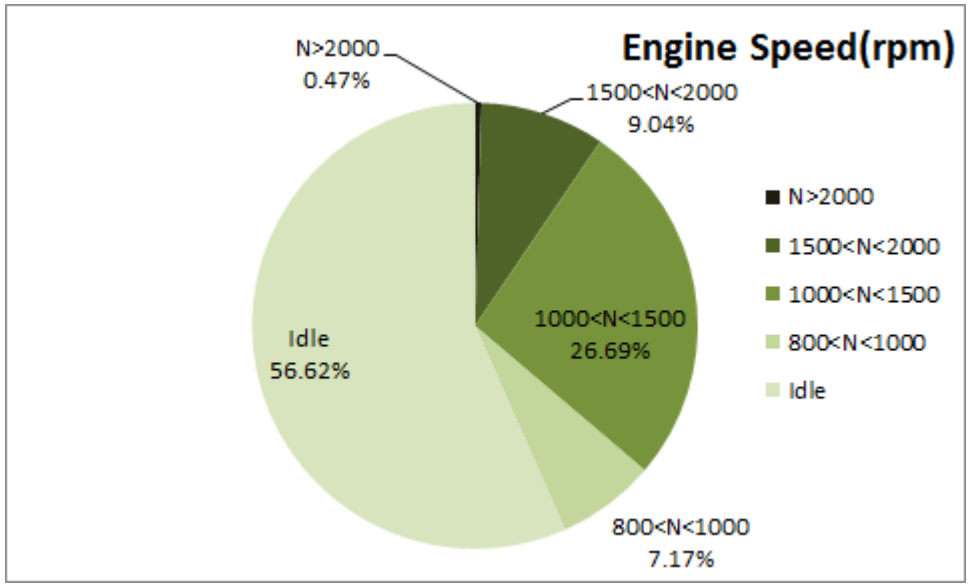
Experiences from Retrofit Activities in Tehran / Learning Issues

Driving and Maintenance Culture

Risk of High Idling Time

- Fuel wasting
- Additional pollution emission

- Long idle operation at two end side stations of line (driver culture)
- Long idle operation at operational terminal
- Many repeated idle operations at maintenance terminal for some days even weeks!



How to Reduce Risk of High Idling?

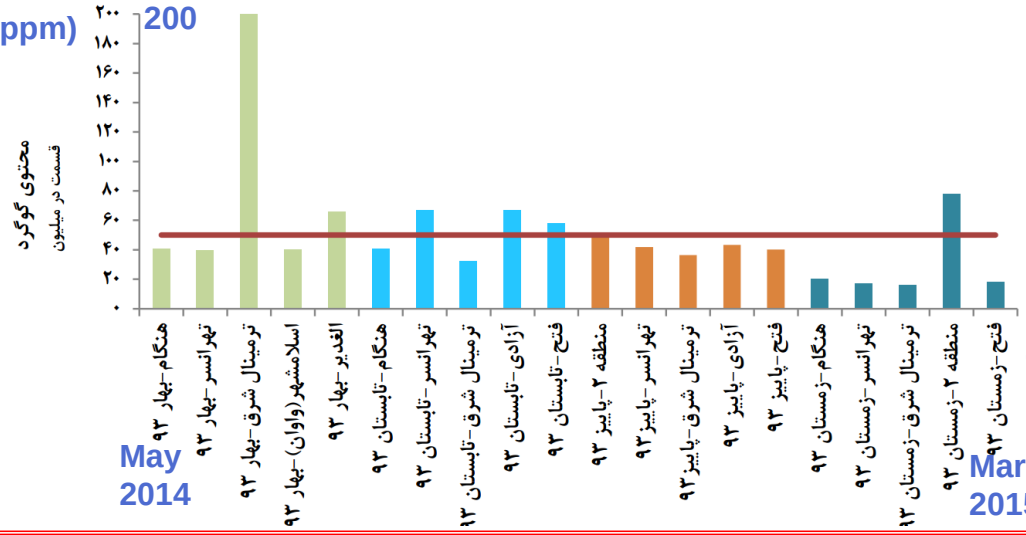
1. Training and raising awareness of high idling risk
2. Installation of on-line data loggers plus central data processing → automatic warning or
3. DPF's ECU data downloading and processing regularly

Experiences from Retrofit Activities in Tehran / Learning Issues

Fuel Quality

Drastic Fuel Quality Improvement

Sulfur content (ppm)

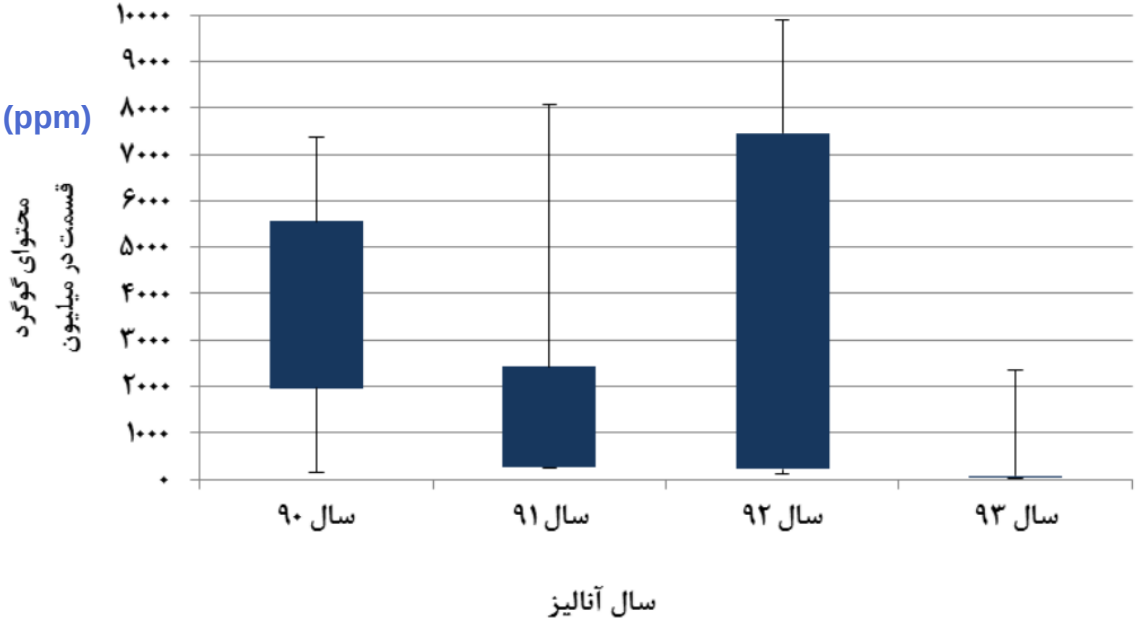


May 2014

March 2015

Fuel Station of Tehran Metropolis

Sulfur content (ppm)



منبع: مریم نادری، وحید حسینی "پایش کیفیت سوخت بنزین و دیزل شهر تهران- سال های 1390 تا 1393"، گزارش فنی شرکت کنترل کیفیت هوا، شماره QM94/02/01/(U)/01– تیر 1394

Experiences from Retrofit Activities in Tehran / Learning Issues

Technology Performance

Tehran Program Test Matrix

Test Matrix of Tehran DPF Program							
Fuel Sulfur content	Type of DPF Technology / Engine testing / Bus running	Active			Passive		
		electrical heater + FBC	post injection	diesel burner	FBC	CDPF	CRT
50 ppm	engine testing	-	-	-	-	-	-
	pilot fleet running	√	-	-	√	√	-
230 ppm	engine testing	√	√	√	√	√	√
	pilot fleet running	-	-	-	-	-	-
7000 ppm	engine testing	√	√	-	√	√	-
	pilot fleet running	-	-	-	-	-	-

Pilot fleet general information		
Emission level	Key tech.	Ave. mileage of selected pilot fleet
Euro III	EGR	> 220,000 km
note: tested engine emission level was Euro II		

DPF Cleaning Creterias
Continues back pressure: 250 mbar (10 S)
Maximum back pressure:

Overall Status of DPFs

DPF Code		1X	2X	1Y	2Y	1Z	2Z	3Z	4Z
Working Line		Line 10- South to North Line		Line 2 – West to East Line		Line 4 – South to North Line			
Working Days		316	50	320	21	480	371	273	325
Mileage (km)		49,700	8,000	42,800	2,500	75,000	47,550	38,000	55,500
First cleaning	mileage	23,644	-	30,800	3 times cleaning	36,000	13,253	26,500	-
	comment	-	low working days	-		-	Doesing system was not adjust	-	-
Second cleaning	mileage	43,700	-	-	not suitable for low temp. line	-	-	few thousands	-
	comment	-	-	-		-	-	cleaning procedure was not Ok	-

Passive - FBC

- Compatibility with high sulfur fuel: passed 7000 ppm
- Average additive consumption: 500 cc/1000 fuel lit.
- Max mileage between two cleanings (best sample): 39000 km
- Min mileage between two cleaning (worst sample): 24000 km
- Maximum detected temperature (safety issue): < 600 ℃
- Price: ?!

Passive - CDPF

- Compatibility with high sulfur fuel: passed 230 ppm
- Mileage : 8000 km (50 days)
- Back pressure since installation: 110 to 120 mbar
- Maximum detected temperature (safety issue): 450 ℃
- Price: ?

Experiences from Retrofit Activities in Tehran / Learning Issues

Fleet Management

Unique Geographical Conditions of Tehran

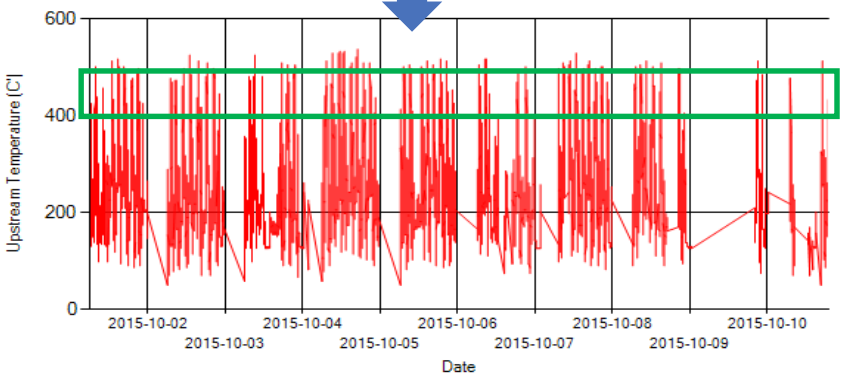
3.9%

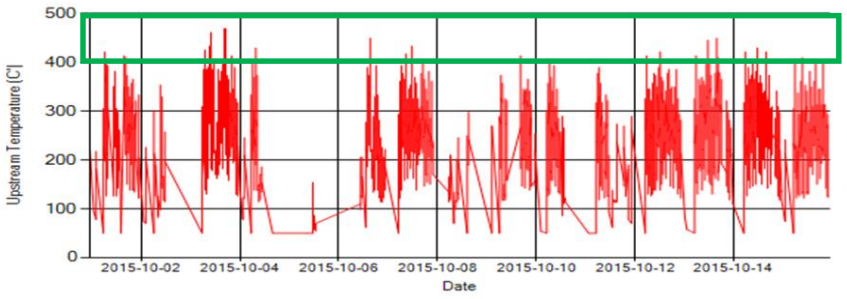
2.23

0.33%

416

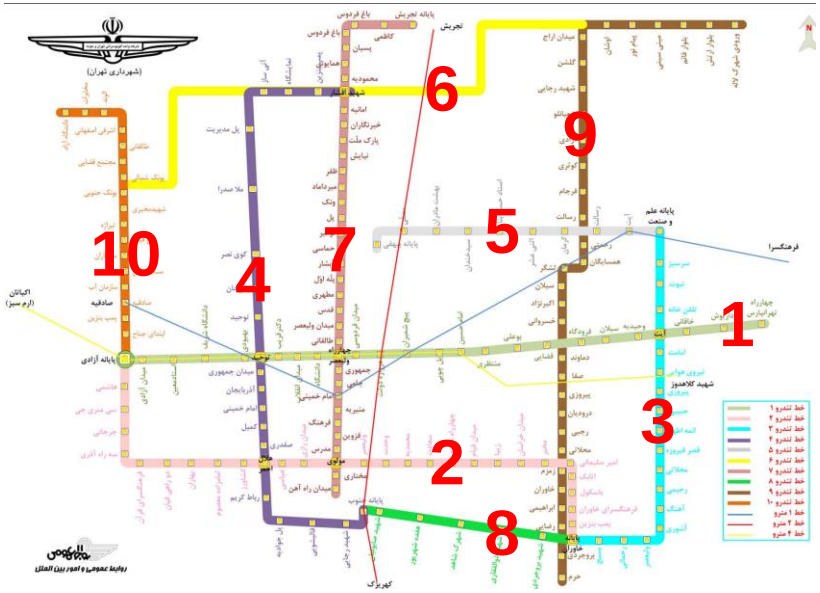
10700





Two Group Lines and Two Types of DPF

- ✓ Group A: Lines 3, 4, 7, 9, 10
- ✓ Group B: Lines 1, 2, 5, 8, 6(?)
- ✓ Bus sharing inside each group is allowed
- ✓ None of buses in group A should be driven in lines of group B



Low cost DPF technology can be used for group A's buses compare to group B

Innovation in Management Is Necessary

Innovation in Operation Management, Maintenance Management and Fleet Organization

COST and RISK


Discussions are welcome
Thank you for your attention