



**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

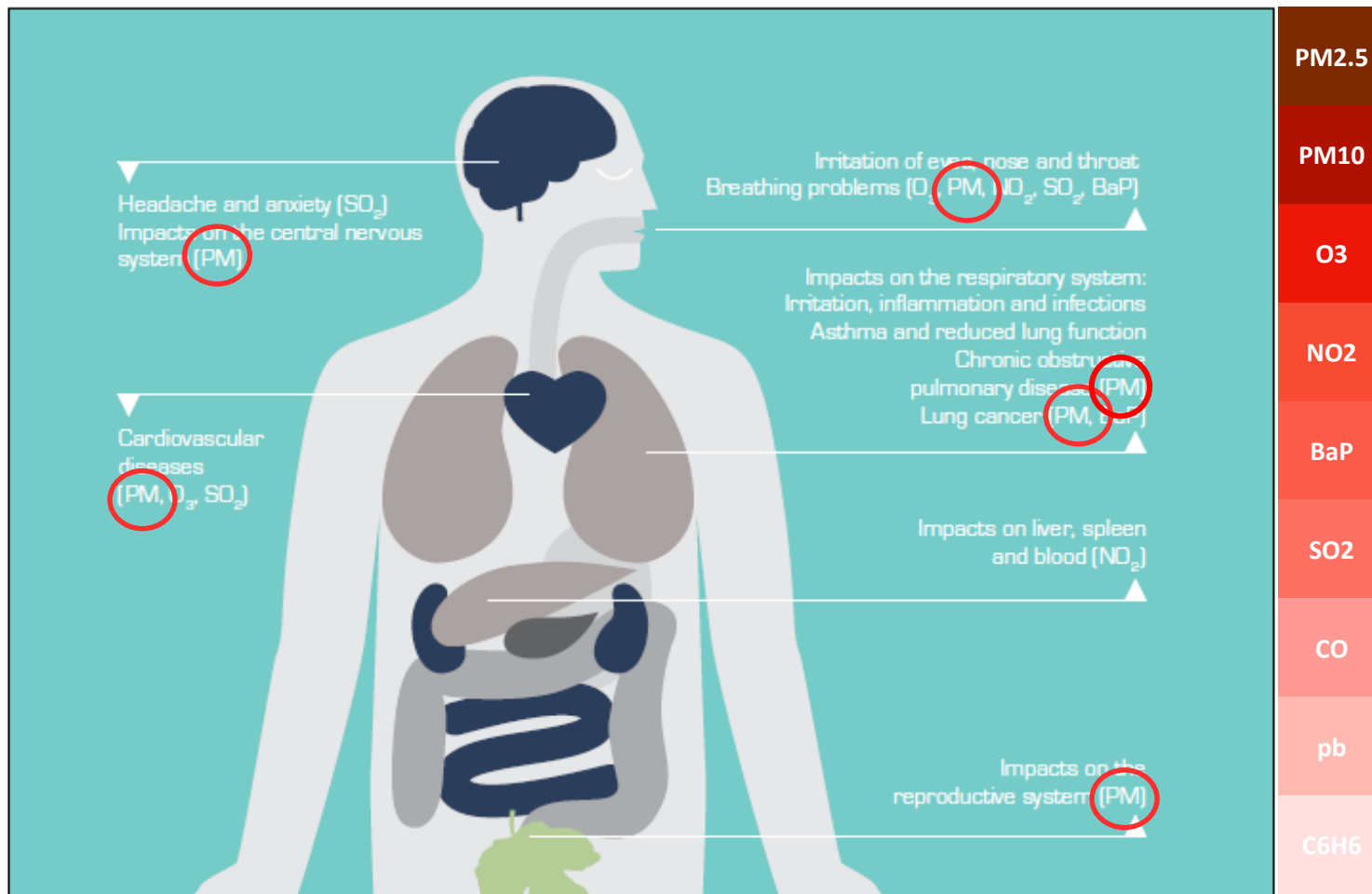
- Requirements for successful retrofit
- Case study Tehran retrofit
- Learning and best practice for Iran retrofit program

## Experiences from Retrofit Activities in Tehran / Requirements

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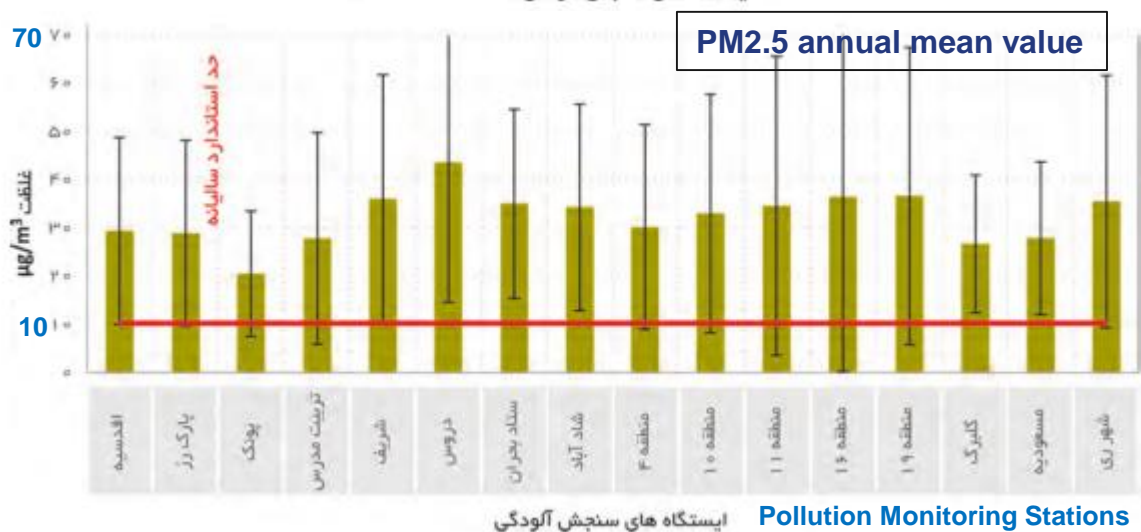
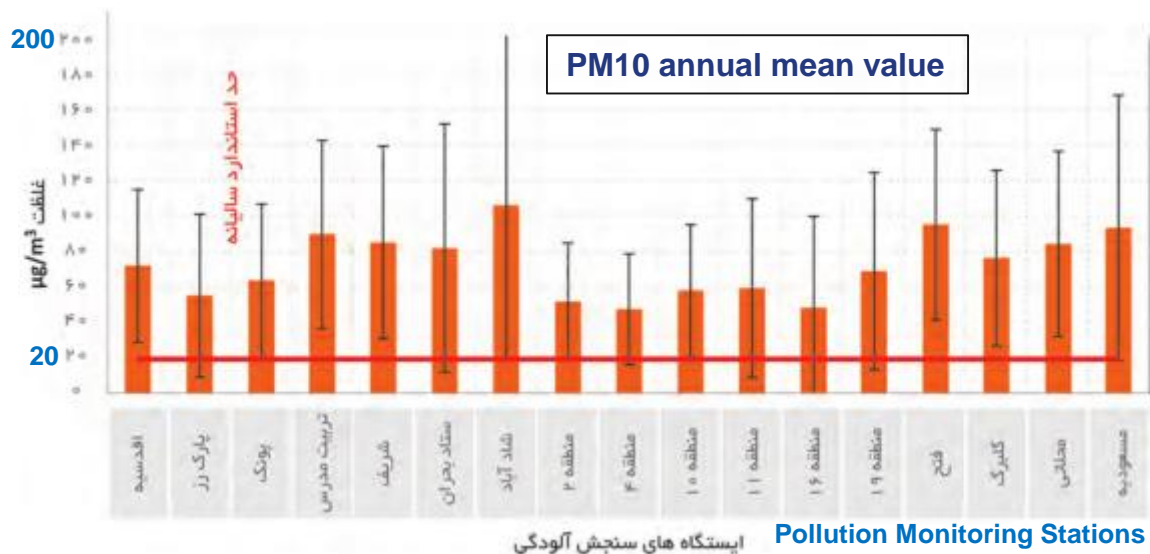
### The Problem

# Air Pollutants and Their Health Impacts



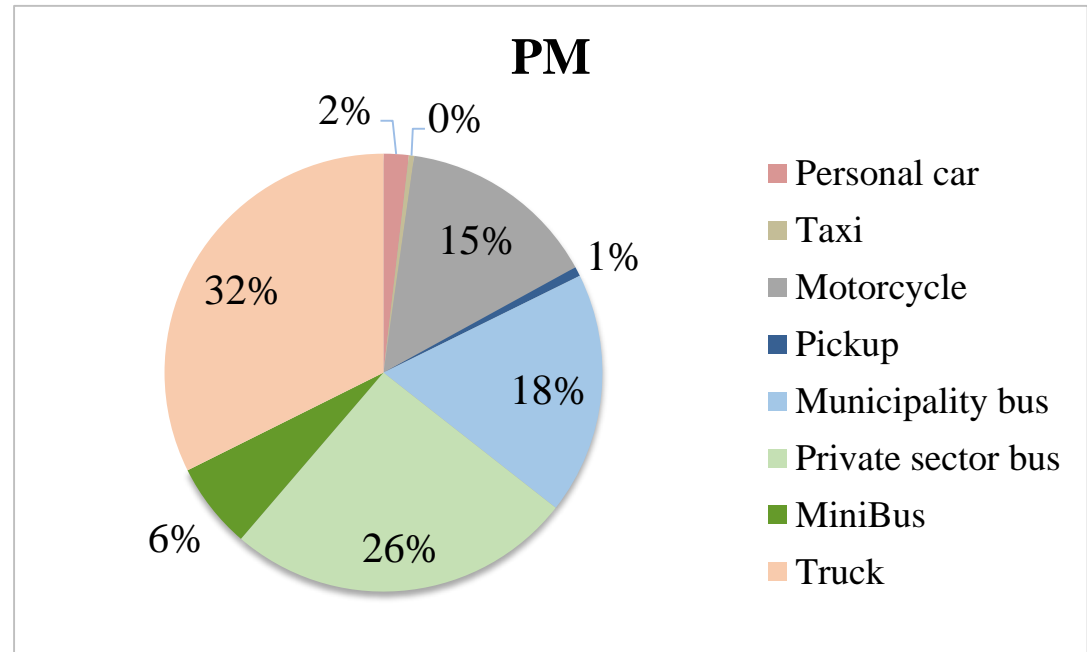
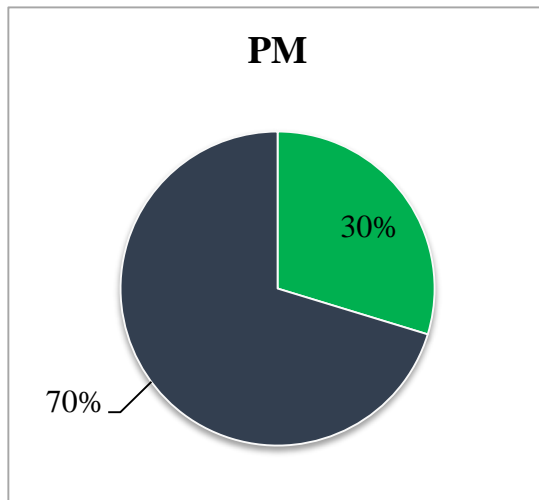
Source: Air quality in Europe – 2013 report, European Environment Agency

# Tehran PM problem



منبع: شرکت کنترل کیفیت هوا، گزارش سالانه کیفیت هوای تهران در سال ۱۳۹۳، 1/QM94/02/02(U)، خرداد ماه ۱۳۹۴

# Contributions of Tehran Primary PM Sources



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

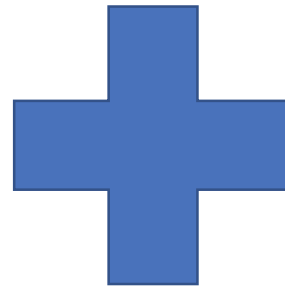
## Experiences from Retrofit Activities in Tehran / Requirements

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**The Solution**

# Fuel and Particulate Filter

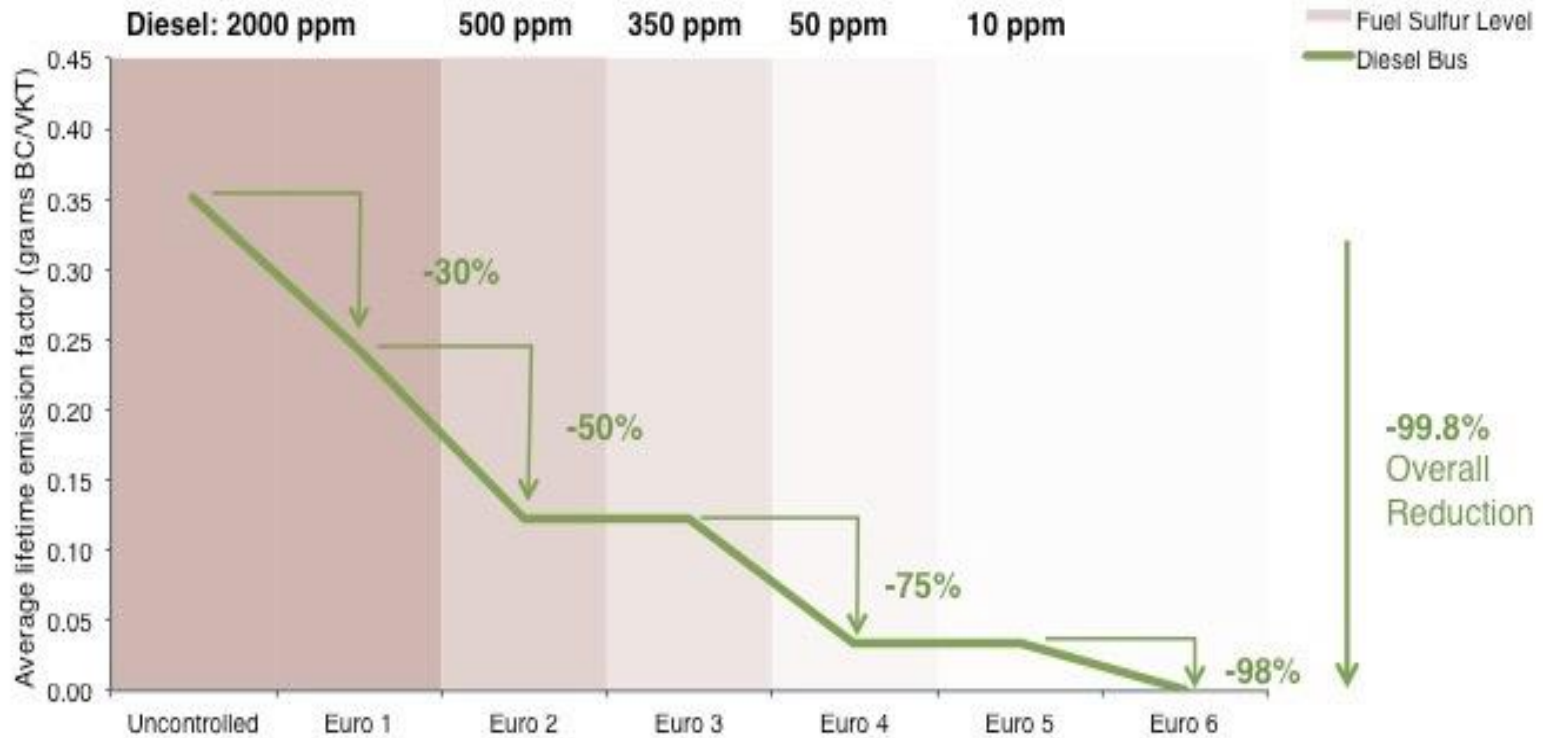
Low Sulfur  
Diesel Fuel





# 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

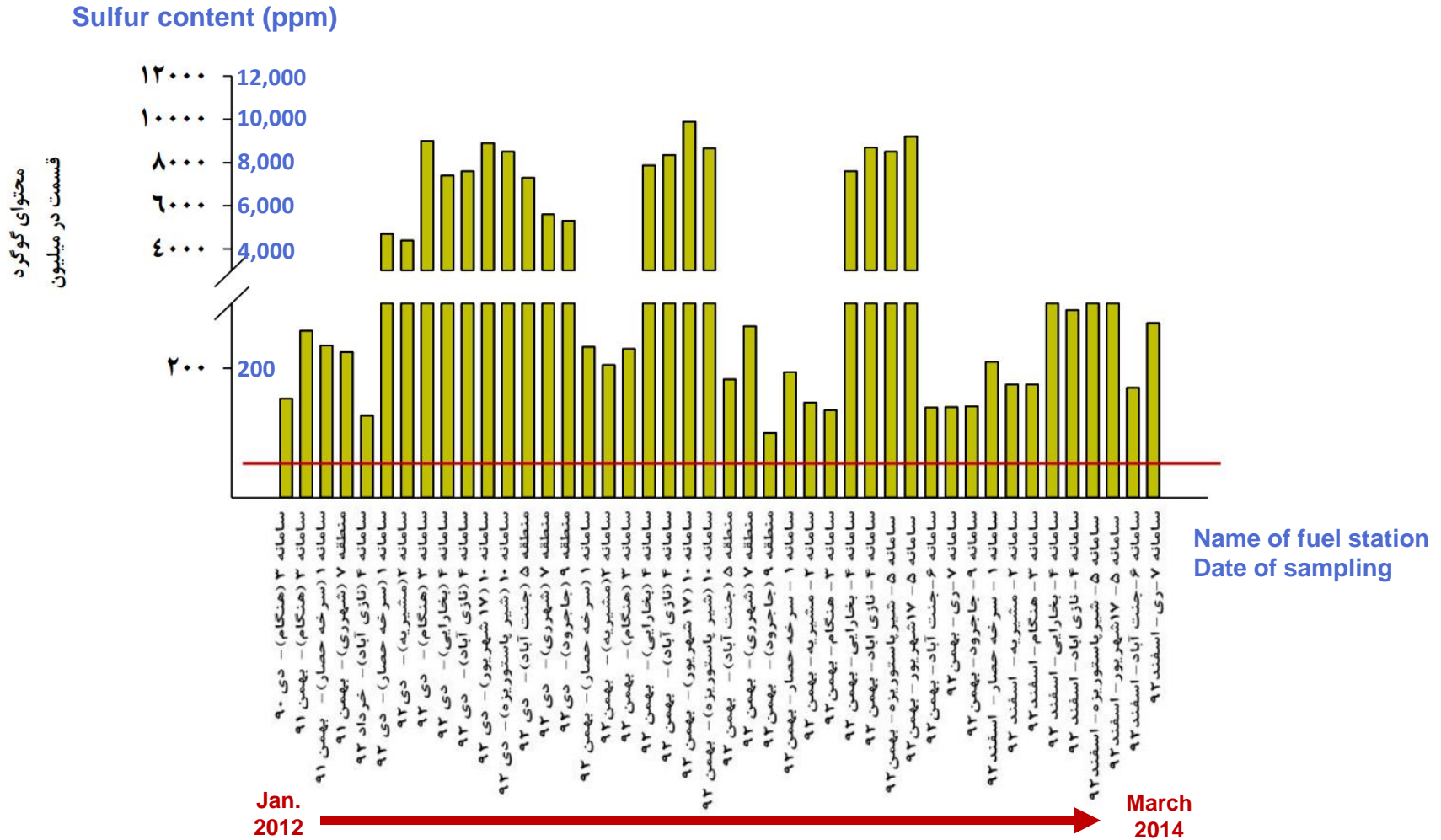
Source: ICCT, Soot-free urban bus fleet report, 2015

## Experiences from Retrofit Activities in Tehran / Requirements

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### The Challenge

# Diesel Fuel Sulfur Content of Tehran BRT Fleet



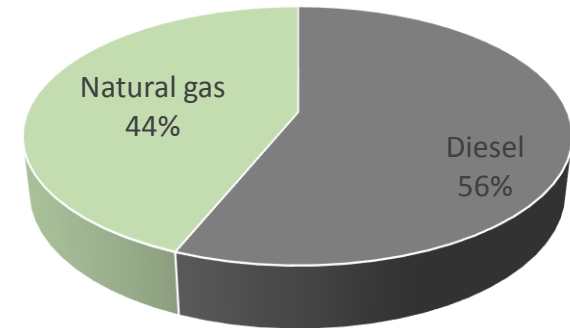
# Fleet Technology Diversity (Tehran case)

## 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

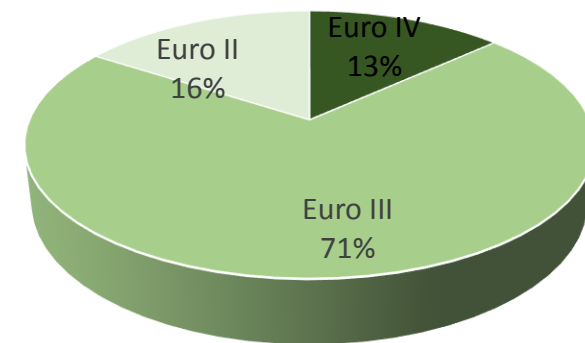
## Fuel Classification



## 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



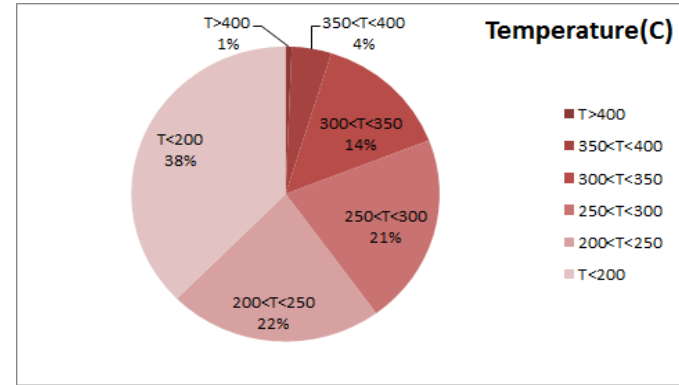
# Different Routes (Tehran case)



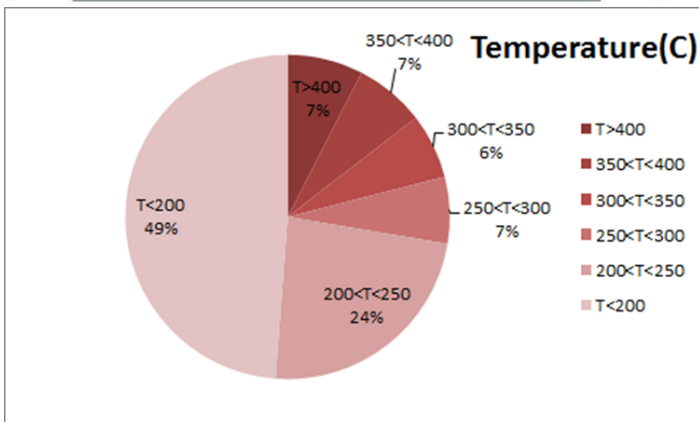
## جدول مشخصات و رنگ خطوط سامانه های تندرو

خط	رنگ	پایانه
خط ۱	قرمز	چهارراه تهرانپارس - پایانه آزادی
خط ۲	بنفش	پایانه خاوران - پایانه آزادی
خط ۳	سبز	پایانه خاوران - پایانه علم و صنعت
خط ۴	آبی	پایانه جنوب - پایانه افشار
خط ۵	بنفش	پایانه بیهقی - پایانه علم و صنعت
خط ۶	زرد	پایانه لاله - پایانه افشار
خط ۷	سبز	میدان راه آهن - پایانه تجریش
خط ۸	قرمز	پایانه جنوب - پایانه خاوران
خط ۹	سبز	پایانه مترو جوانمرد قصاب - پایانه لاله
خط ۱۰	قهوه‌ای	دانشگاه آزاد علوم تحقیقات - پایانه آزادی

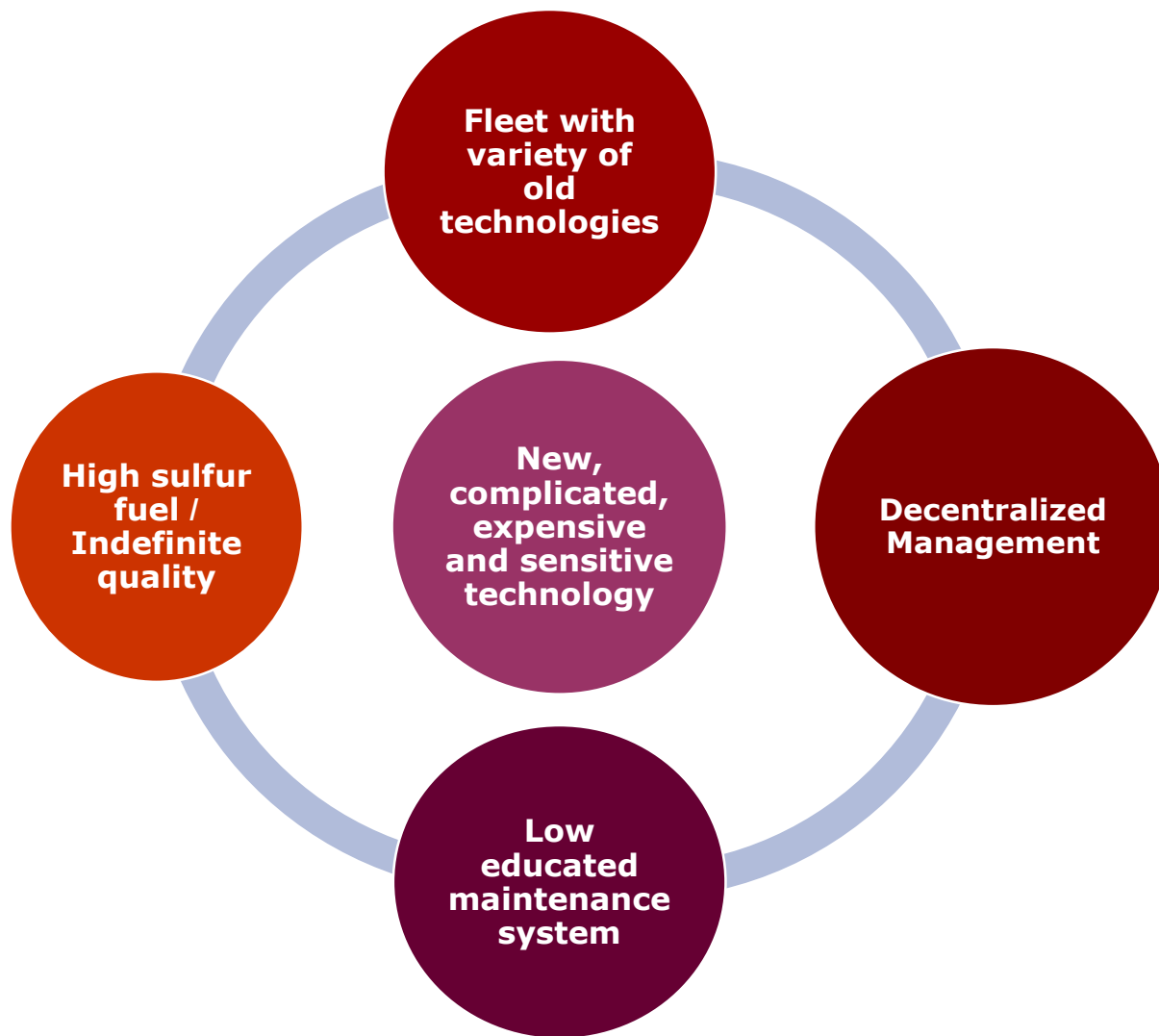
## 260 Lines



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

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**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

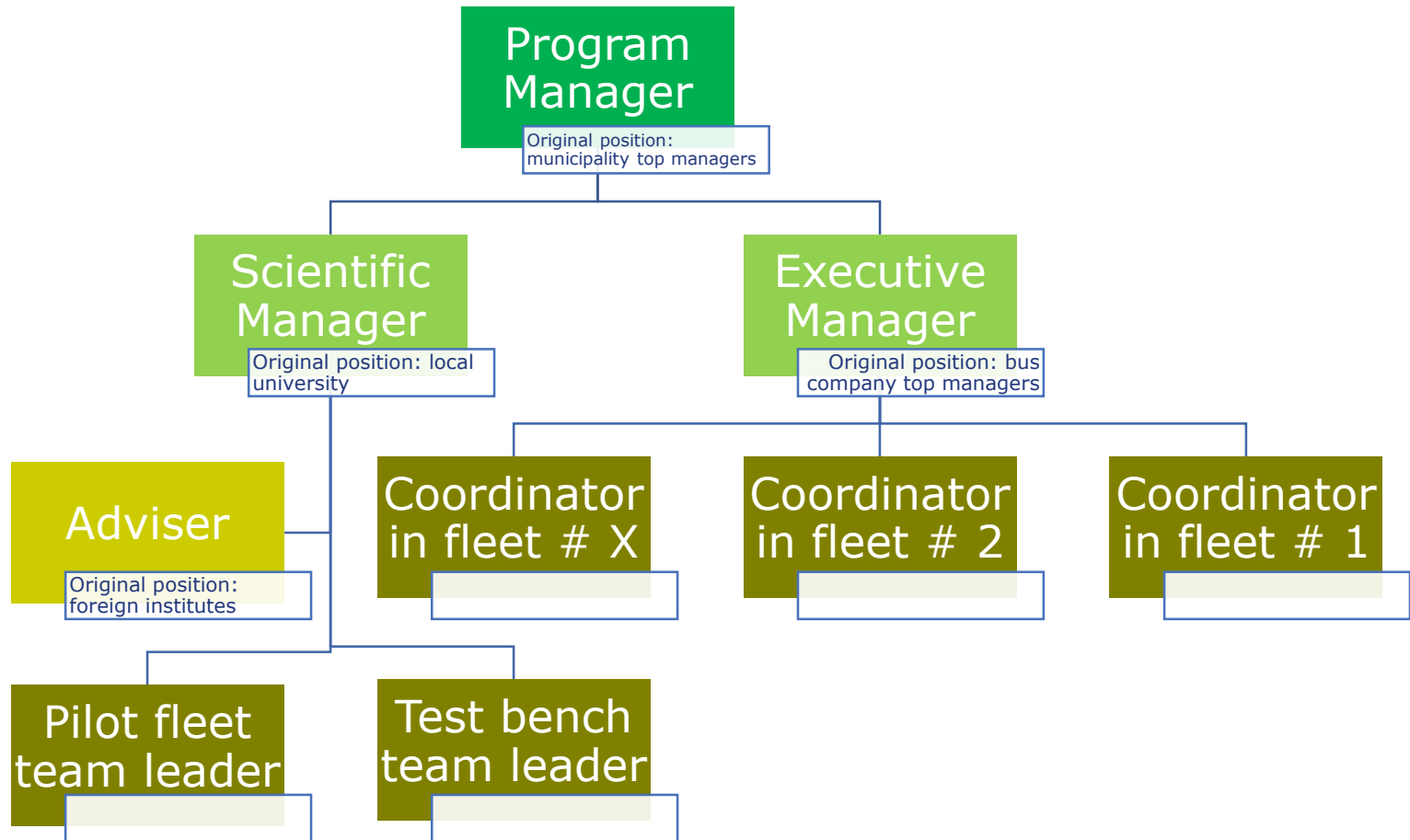
- ❑ **Classification of stakeholders (drivers, Inspectors, maintenance technicians, workshop managers, ...)**
- ❑ **Providing training materials in different levels and different scopes**
- ❑ **Train courses planning and implementation**
- ❑ **On-job training, Educational posters, ...**

# Engine and Pilot Fleet Testing

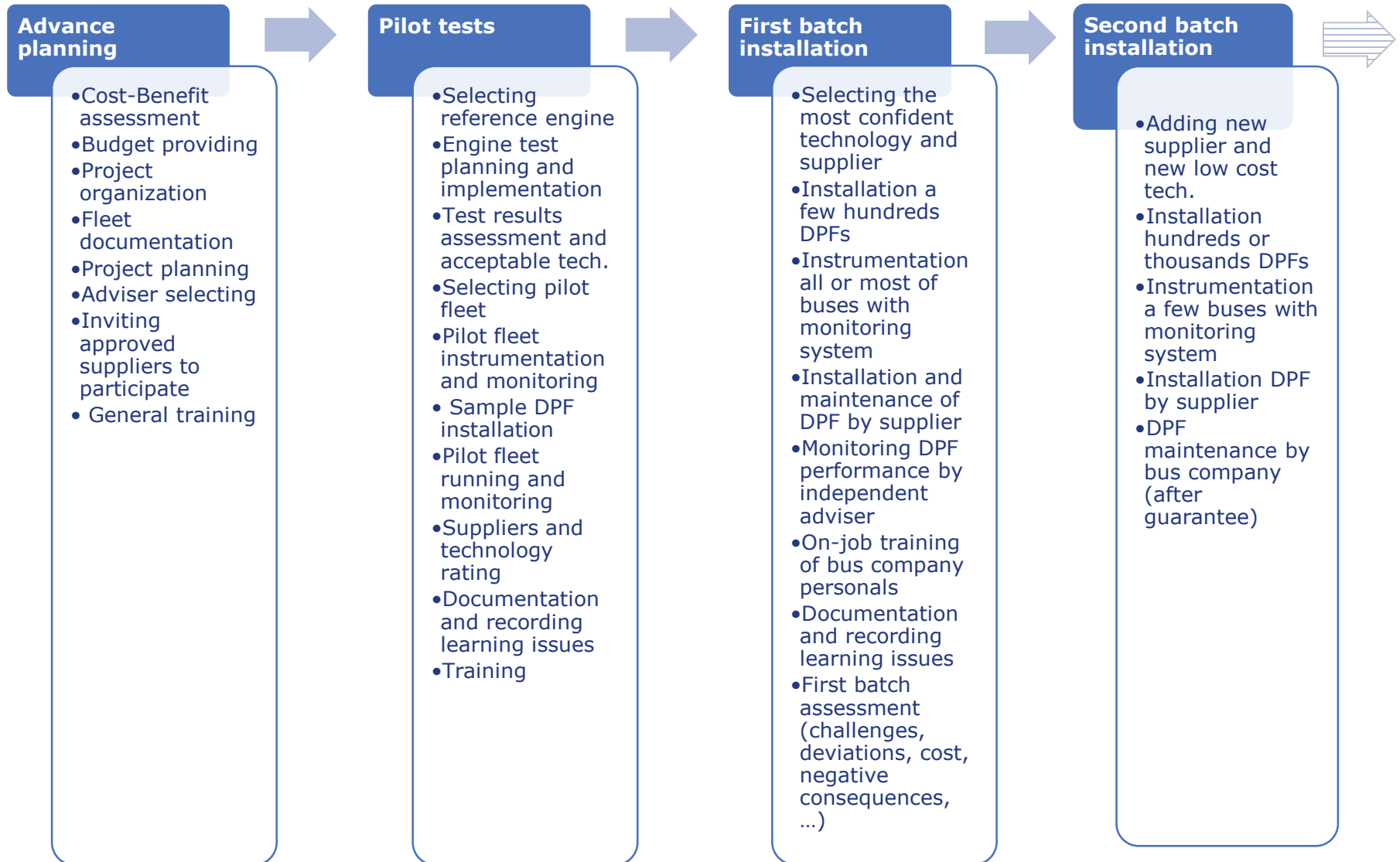
- Engine test planning**
- Selecting different type of DPF technologies (low cost to expensive)**
- Selecting proper engine model**
- Engine testing with different fuels**
- Installation accepted DPFs on pilot fleet**
- Running and monitoring pilot fleet on real world**

- ❑ **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



## **Experiences from Retrofit Activities in Tehran / Case Study**

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### **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

Taa

### 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

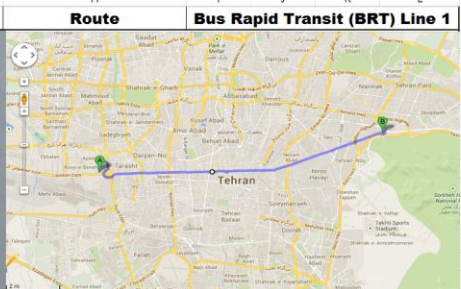

# Vehicle Data Base

BUS REPORT - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW

Clipboard Font Alignment Number Styles

Q35

General Information		Smoke Measurement	Route	Bus Rapid Transit (BRT) Line 1
Licence Plate / Registration number	33453	<b>TEST RESULTS</b>  <b>FREE ACCELERATION</b> IDLE CUT OIL ACT OPC RPM RPM T t k [min <sup>-1</sup> ] [°C] [s] [m <sup>-1</sup> ] 550 2080 76 1.24 2.04 550 2090 77 1.10 1.92 550 2090 77 1.24 1.98 550 2100 77 1.23 1.97  ARITHMET.MEAN VALUE k 1.97 [m <sup>-1</sup> ] BANDWIDTH OF RESULTS k 0.12 [m <sup>-1</sup> ]		
Mileage at the time of smoke measurement (km)	157193			
Bus type and Model	KINGLONG Articulated			
Production Date	2011			
Model	XMQ 6180G1			
Series No	AA800234			
Engine No	50428141192799			
VIN	LA6B1N1M8BB300564			
Weight on front axis (kg)	6000			
Weight on rear axis (kg)	10000			
Weight on middle axis (kg)	11500			
Total weight loaded (kg)	27500			
Maximum speed (km/h)	80			
Fuel tank capacity (lit)	250			
length (mm)	17900			
width (mm)	2550			
height (mm)	3150			
min height from ground (mm)	140			
min rotation radius (m)	12			
Engine Specs				
Model	MAN D2066LOH12			
Type	6-Cyl, in-line, water-cooled, 4-stroke with turbocharger and intercooler			
Bore (mm)	128			
Stroke (mm)	155			
Displacement volume (mL)	11976			
Maximum rated brake power (hp)	350			
Maximum rated torque (Nm) @1000-1400 rpm	1750			
idle speed (rpm)	550±50			
Maximum rated speed at idle (rpm)	2200			
Compression ratio	19.0±0.5:1			
Lubricating oil	Lai Ke CI-4/SL 15W/40			
			Western Bus Terminal of Tehran	Tehranpars Bus Terminal
			total distance (Km)	19

COVER 32923 32895 32938 32914 33453 33469 33457 85156

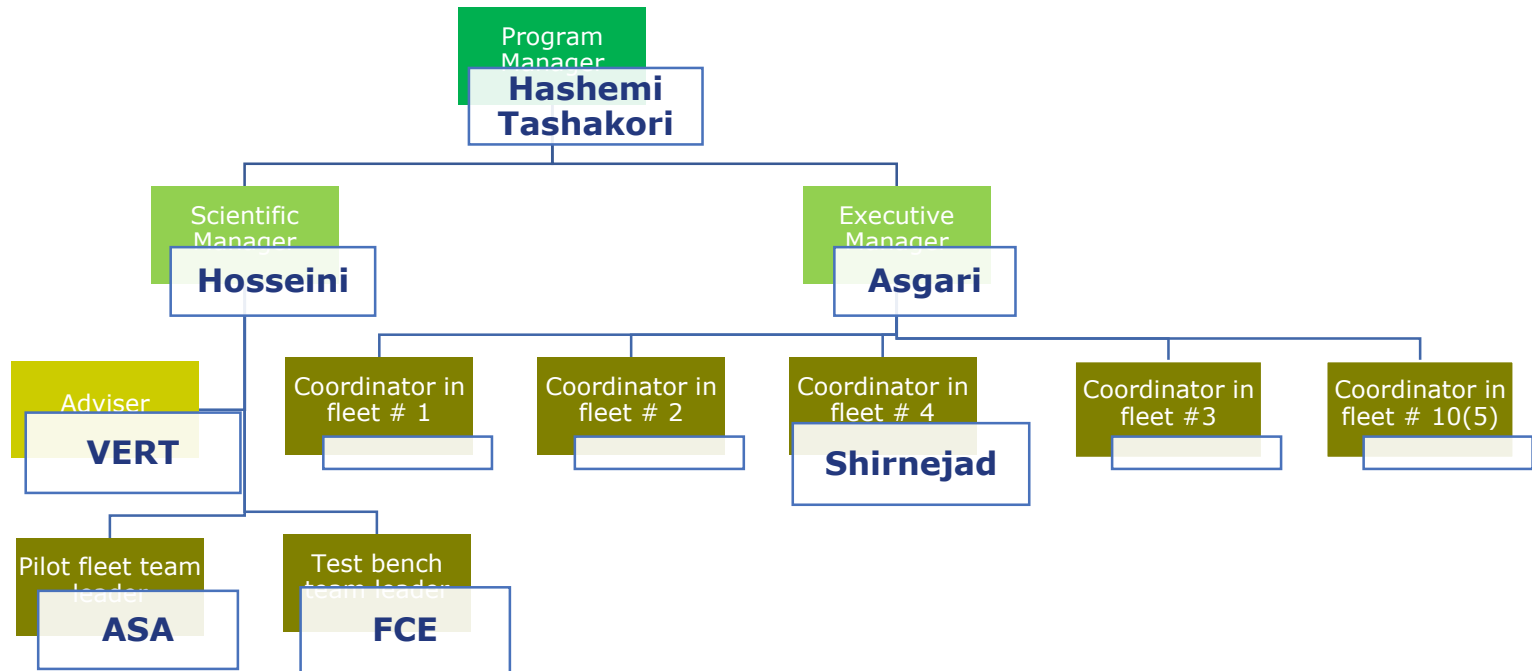
READY

## Experiences from Retrofit Activities in Tehran / Case Study

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### Project Organization

# Tehran DPF Project Organization



## Experiences from Retrofit Activities in Tehran / Case Study

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### Project Planning

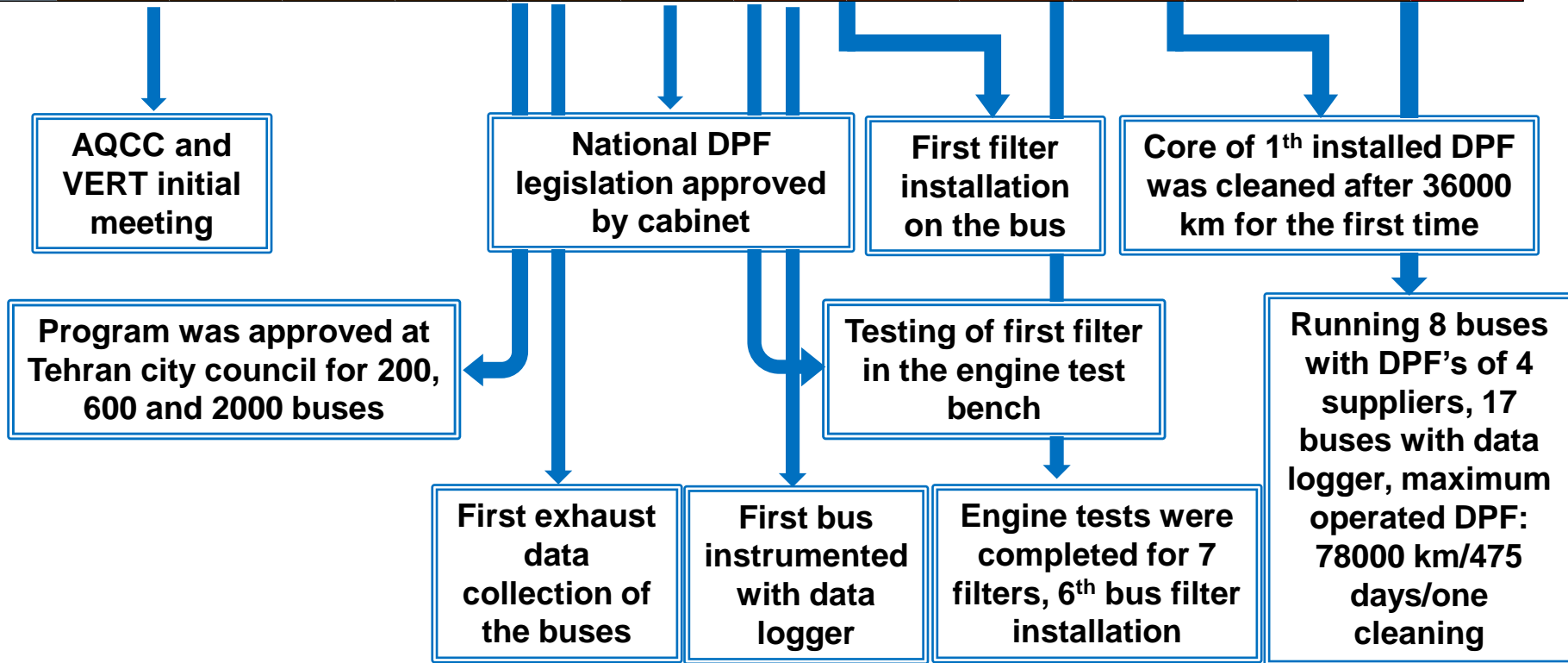
# Tehran DPF Project Progress

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



## Experiences from Retrofit Activities in Tehran / Case Study

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### 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...

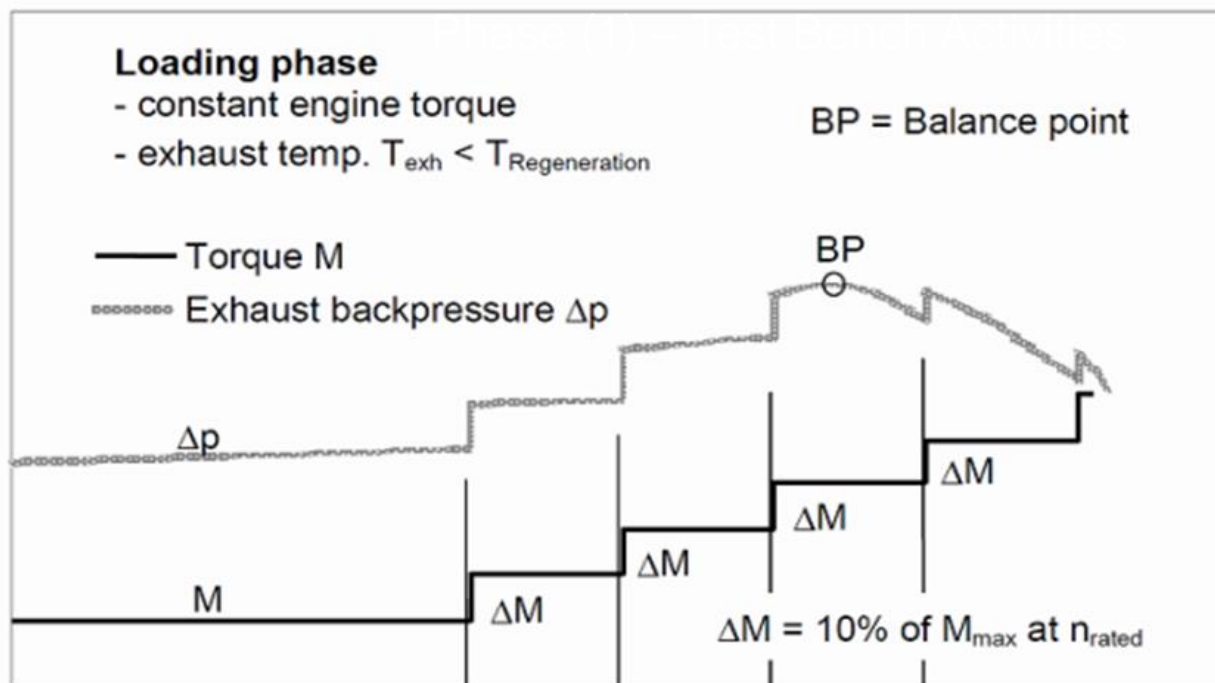
# Tested Engine Type

<b>Manufacturer / type</b>	<b>IDEM(OM457)</b>
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 <sup>3</sup> ]
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 <sup>-1</sup> ]
Max. Torque @ RPM	1250 [Nm] @ 1100 [min <sup>-1</sup> ]
Max exhaust temperature downstream TC @ nominal RPM	500° C @ 1000 [min <sup>-1</sup> ] /
Low idle speed / high idle speed	600 ± 50 [min <sup>-1</sup> ]; 2100 [min <sup>-1</sup> ]



# 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

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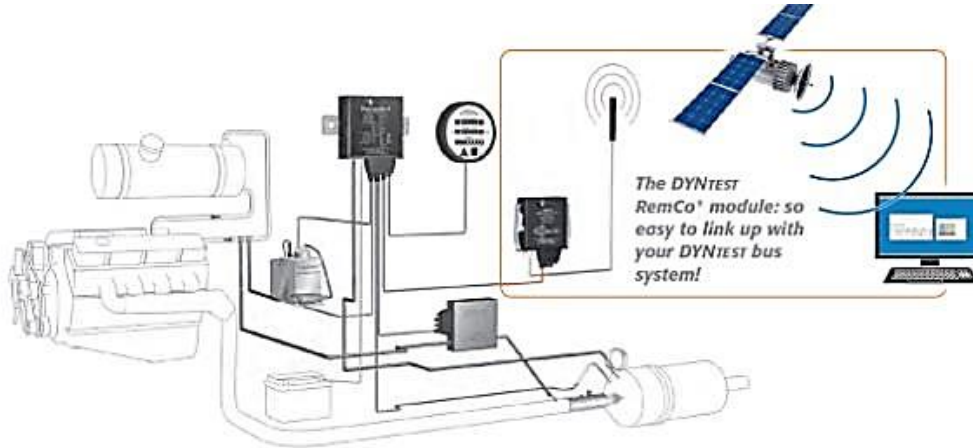
### Pilot Fleet Monitoring Before DPF Installation

# 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



CPK Automotive - GSM G...  
78.46.48.245/content.php

Home You are logged in as Project Iran logout Administration

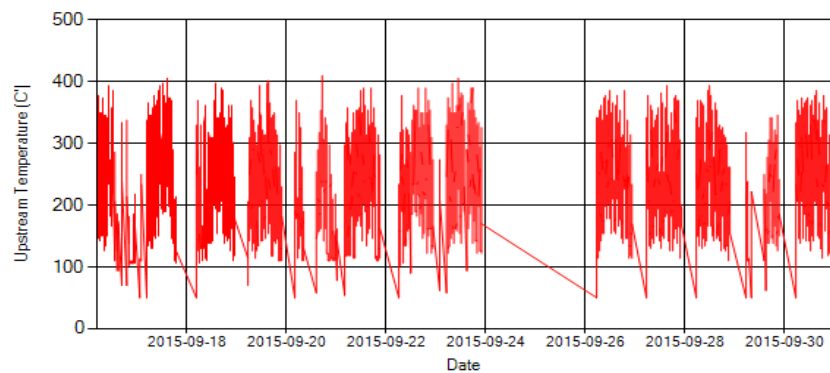
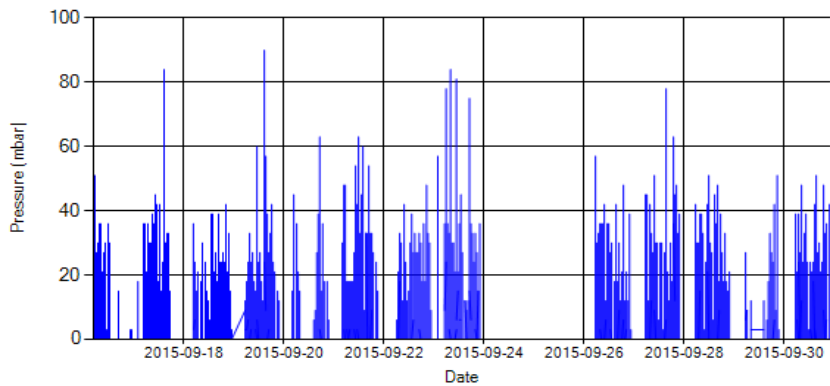
**CPK Automotive**  
Member of the Heinzmann Group

Welcome Project Iran -

Filter

Project	Vehicle ID	System	Install. Date	Vehicle Description	Fleet	Date, Time	Status	last known position	Action
PURtech	78-524 Line 4	LN: 001443 DN: 1930	28/Jan/2015	01 PURtech Installed (28/Jan/2015)	Iran	16.12.2015 09:45	In Motion	35.79052 : 51.41633	
Dinex	78-515 Line 4	LN: 001460 DN: 1954	22/Oct/2014	01 Dinex Installed (22/Oct/2014)	Iran	18.09.2015 09:35	In Motion	35.65126 : 51.41908	
	85-156 Line 10	LN: 001491 DN: 1930		CPK Problem (Date)	Iran	29.11.2014 11:14	In Motion	35.67239 : 51.30826	
Dinex	33-637(34 119) Line 2	LN: 001492 DN: 1927	02/Jun/2015	02 Dinex Installed (02/Jun/2015)	Iran	16.12.2015 13:57	In Motion	35.64256 : 51.47732	
	32-938 (Removed)	LN: 001493 DN: 1927		Line 3 - ( CPK Temp Sensor Error )	Iran	30.11.2014 10:02	In Motion	35.74635 : 51.49235	
	85-162 (Removed)	LN: 001494 DN: 1927		85162 former CPK- before DPF installation	Iran	08.11.2015 15:21	In Motion	35.74433 : 51.29506	
	33-457 Line 1	LN: 001495 DN: 1927		Engin problem / Out of Service	Iran	27.10.2014 13:42	In Motion	35.74661 : 51.49253	

# Sample Collected Information



Document #:ABL2014DPF009 version: 01 Page:4 of ..		<b>Daily check</b>		
1	driver name			
2	mileage (km)	<b>130247</b>		
3	fueling	Yes <input type="checkbox"/>	No <input type="checkbox"/>	
	if yes then fueling station:	fuel amount (lit): <b>84</b>		
Document #:ABL2014DPF009 version: 01 Page:4 of ..		<b>Daily check</b>		
5	1 driver name			
	2 mileage (km)	<b>130435</b>		
6	3 fueling	Yes <input type="checkbox"/>	No <input type="checkbox"/>	
	if yes then fueling station:	fuel amount (lit): <b>145</b>		
Document #:ABL2014DPF009 version: 01 Page:4 of ..		<b>Daily check</b>		
7	5	1 driver name		
	2 mileage (km)	<b>130638</b>		
8	3 fueling	Yes <input type="checkbox"/>	No <input type="checkbox"/>	
	if yes then fueling station:	fuel amount (lit): <b>160</b>		
	4 adding additive	Yes <input type="checkbox"/>	No <input type="checkbox"/>	
	if yes then additive type:	additive amount (lit):		
	5 adding engine oil	Yes <input type="checkbox"/>	No <input type="checkbox"/>	
	if yes then oil type:	oil amount (lit):		
	6 engine malfunction	Yes <input type="checkbox"/>	No <input type="checkbox"/>	
	if yes please more description:			
	7 maintenance	Yes <input type="checkbox"/>	No <input type="checkbox"/>	
	if yes please more description:			
	8 data logging system	Ok <input type="checkbox"/>	Nok <input type="checkbox"/>	
	if nok please more description:			
Comments:				
	Date:16/10/2014	Time:	Site: 2	Name: Asem
				Signature:



# Sample Parts of Technical Reports

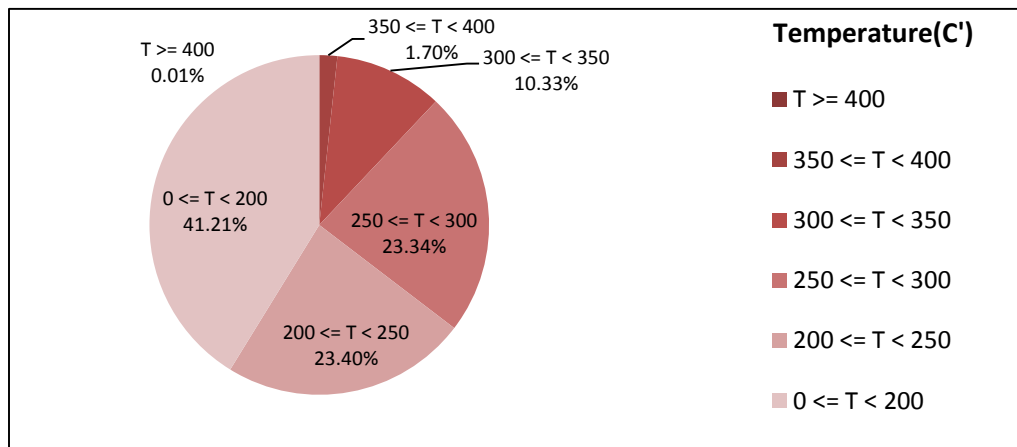
## System and path Overall information

Vehicle plate number	*****
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]

## 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

## Temperature distribution over the working hours



# 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**

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### **Sample DPFs Installation**

# Packaging Investigation and K-value Measurement

## K-value measurement



OPACITY [m<sup>-1</sup>]  
max. 2.50

-----

TEST RESULTS

FREE ACCELERATION

IDLE	CUT	OIL	ACT	OPC
RPM	RPM	T	t	k
[min <sup>-1</sup> ]	[°C]	[s]	[m <sup>-1</sup> ]	
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

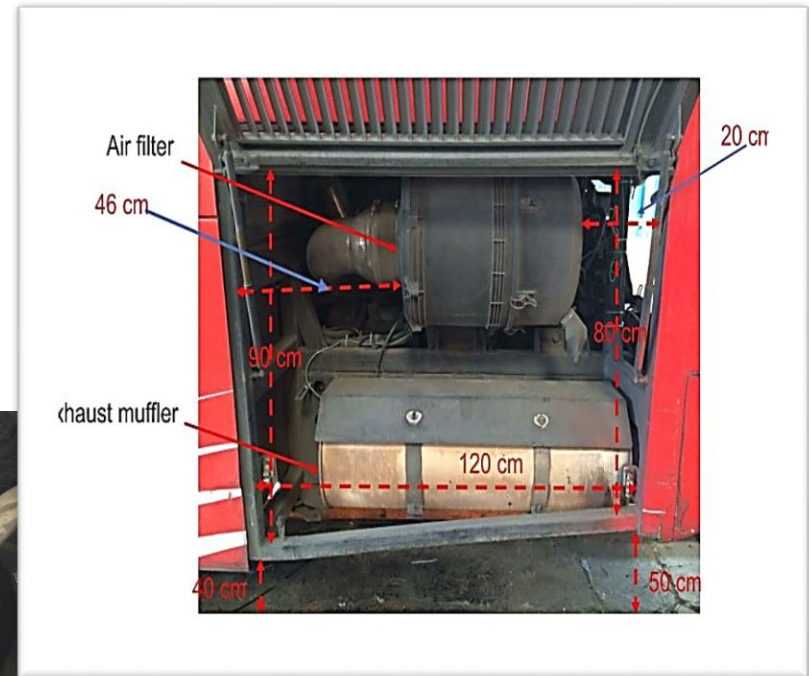
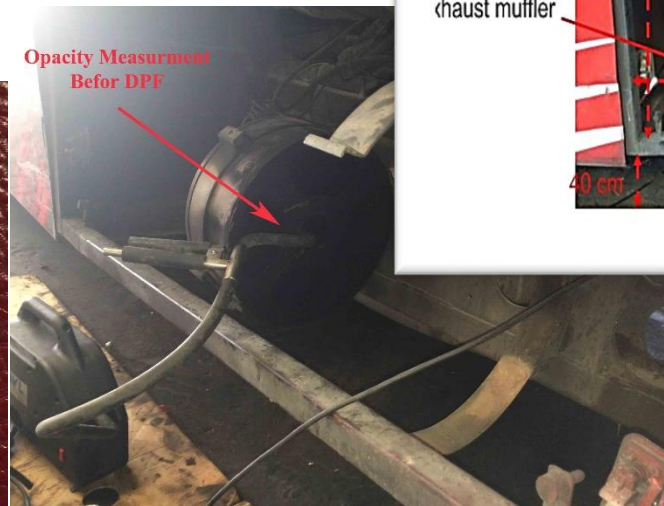
ARITHMET. MEAN VALUE k  
1.01 [m<sup>-1</sup>]

BANDWITH OF RESULTS k  
0.06 [m<sup>-1</sup>]

-----

TEST RESULT:

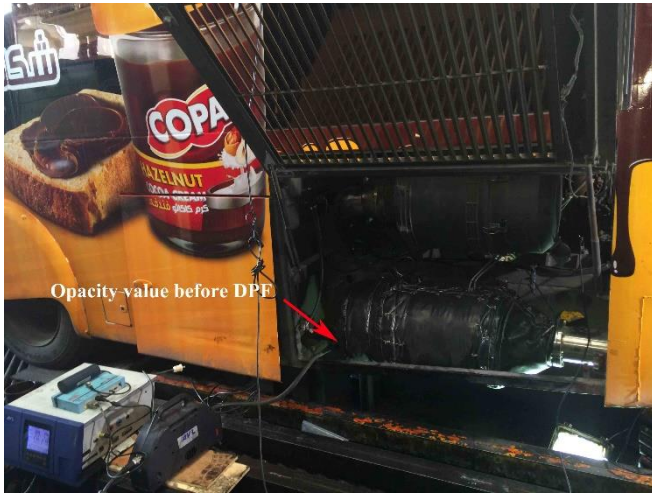
.....



# Sample DPFs Installation-flanges modification



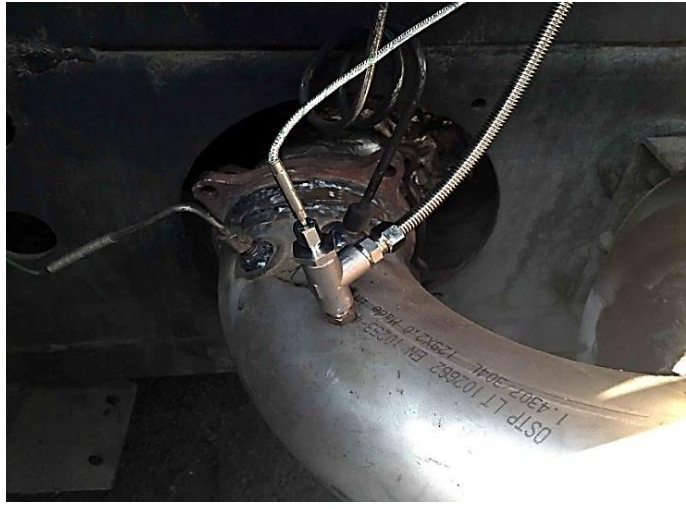
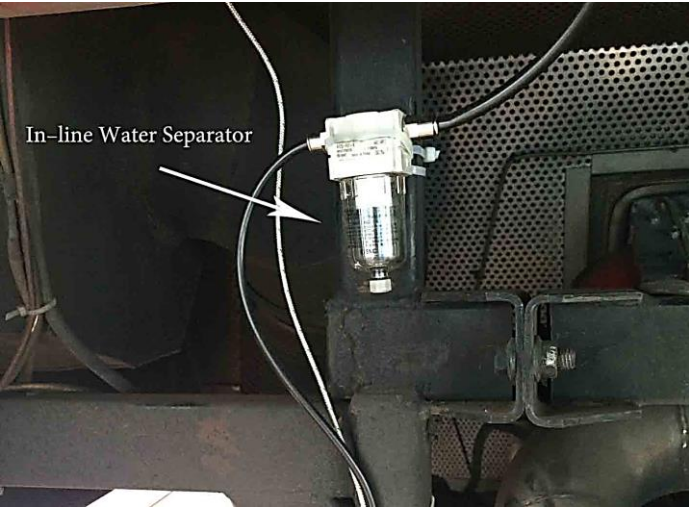
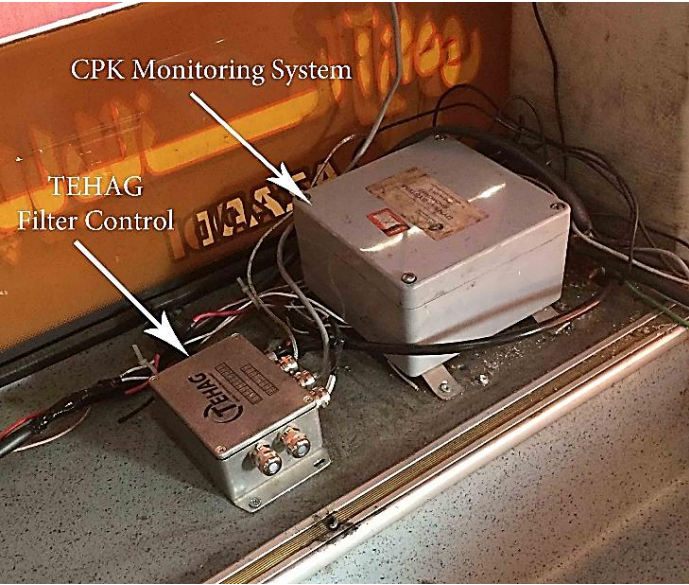
# Sample DPFs Installation



# 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	78***	Line 4	229689	1.80	0.02
22/Oct/2014	A	Passive system + FBC	78***	Line 4	272444	2.00	0.04
28/Jan/2015	C	Passive system + FBC	78***	Line 4	239626	1.70	0.02
19/Feb/2015	B	Active system + FBC	85***	Line 4	280412	1.10	0.02
19/Feb/2015	B	Active system + FBC	33***	Line 2	142717	1.24	0.04
23/Feb/2015	B	Active system + FBC	85***	Line 10	212093	1.60	0.01
02/Jun/2015	A	Passive system + FBC	33***	Line 2	160695	2.00	0.02
24/Sep/2015	D	CDPF (Catalyzed DPF)	85***	Line 10	211553	1.76	0.00

## **Experiences from Retrofit Activities in Tehran / Case Study**

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### **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

Systems periodic status - 2.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW PDF-XChange 4 Sign in

Clipboard Font Alignment Number Styles Cells Editing

A101

System Check List (Active system) 2015

Check Date	Checked Item	Status	Notes	Priority	Maintenance Status	Report Period
2015.12.13	Pressure	✓	Pressure was high due to lack of	High	In Progress	12.06 to 12.13
2015.12.13	Temperature 1	✓		-	-	12.06 to 12.13
2015.12.13	Temperature 2	✓		-	-	12.06 to 12.13
2015.12.13	Engine Speed	✓		-	-	12.06 to 12.13
2015.12.13	Additive	✓	Additive need to be added to	High	In Progress	12.06 to 12.13
2015.12.13	CPK & GPS	✓	Last update was on 12.06 - bus	High	Complete	12.06 to 12.13
2015.12.13	Filter Operation Status	✓		-	-	12.06 to 12.13

READY

# 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



SYSTEM CHECK LIST

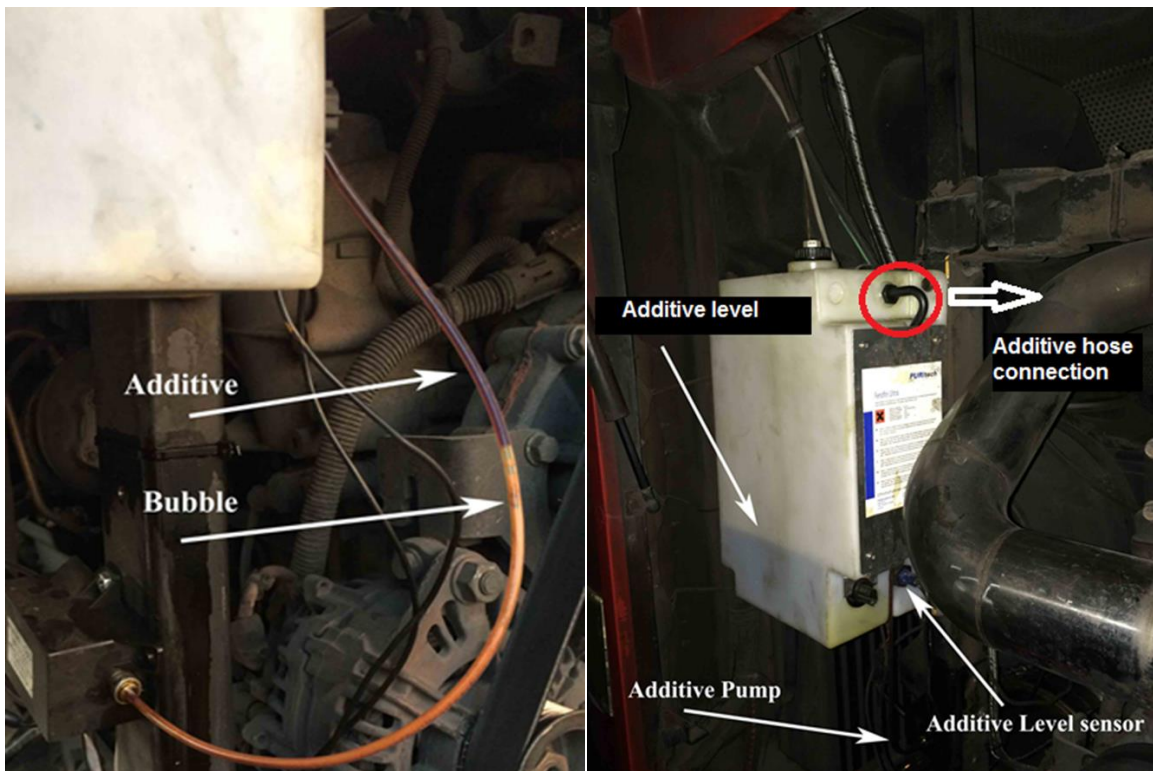
Vehicle Number:		Check Date:		DPF Company:	
Section	Items	OK	Not OK	Problem Specification	Comments/Changes
CPK Section	Pressure Sensor	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
	Temperature 1 Sensor	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
	Temperature 2 Sensor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

# DPFs' ECU Periodic Checking for Problem Detection



# Checking Hardware Systems – system modification

## Additive system problem



## Problem solving

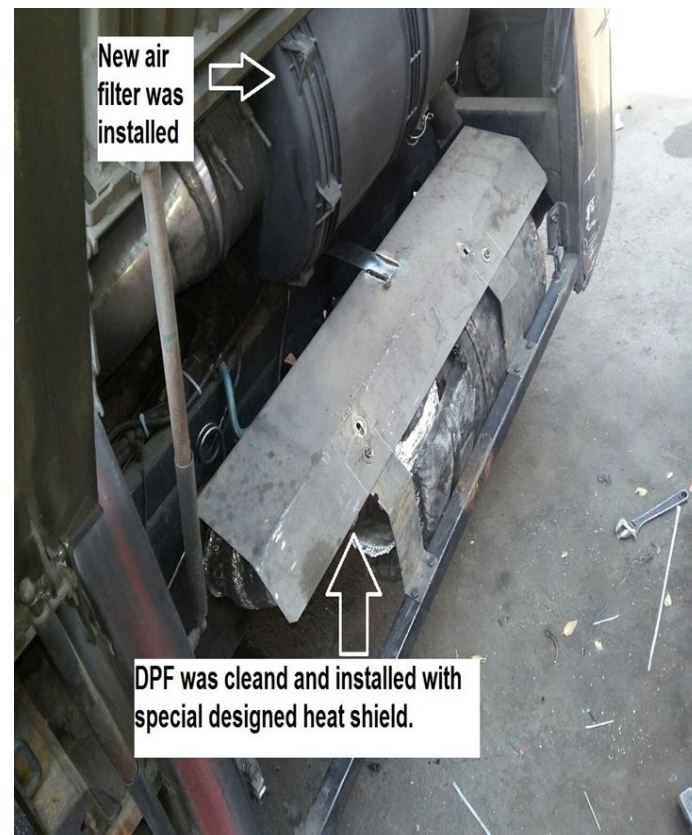




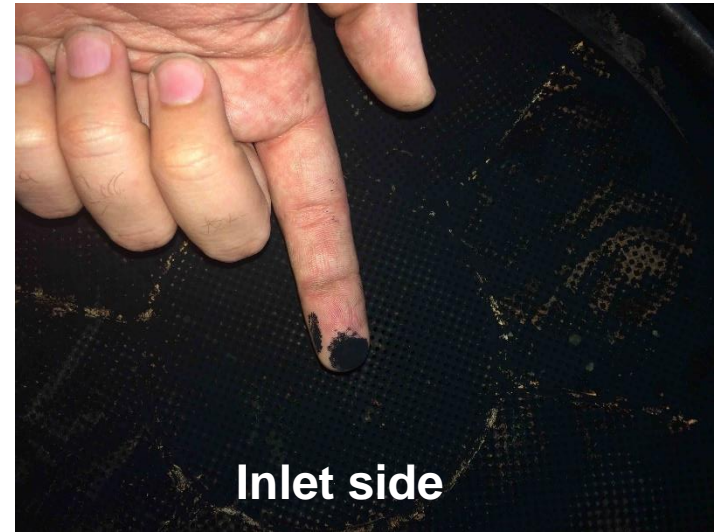
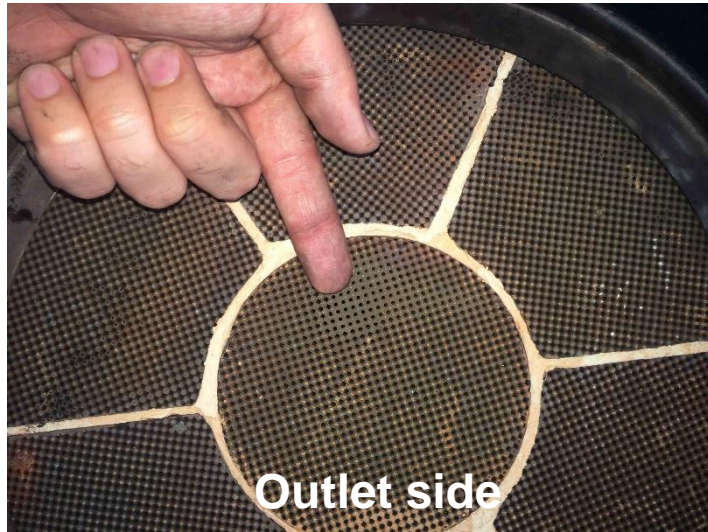
## Isolation system problem



## 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

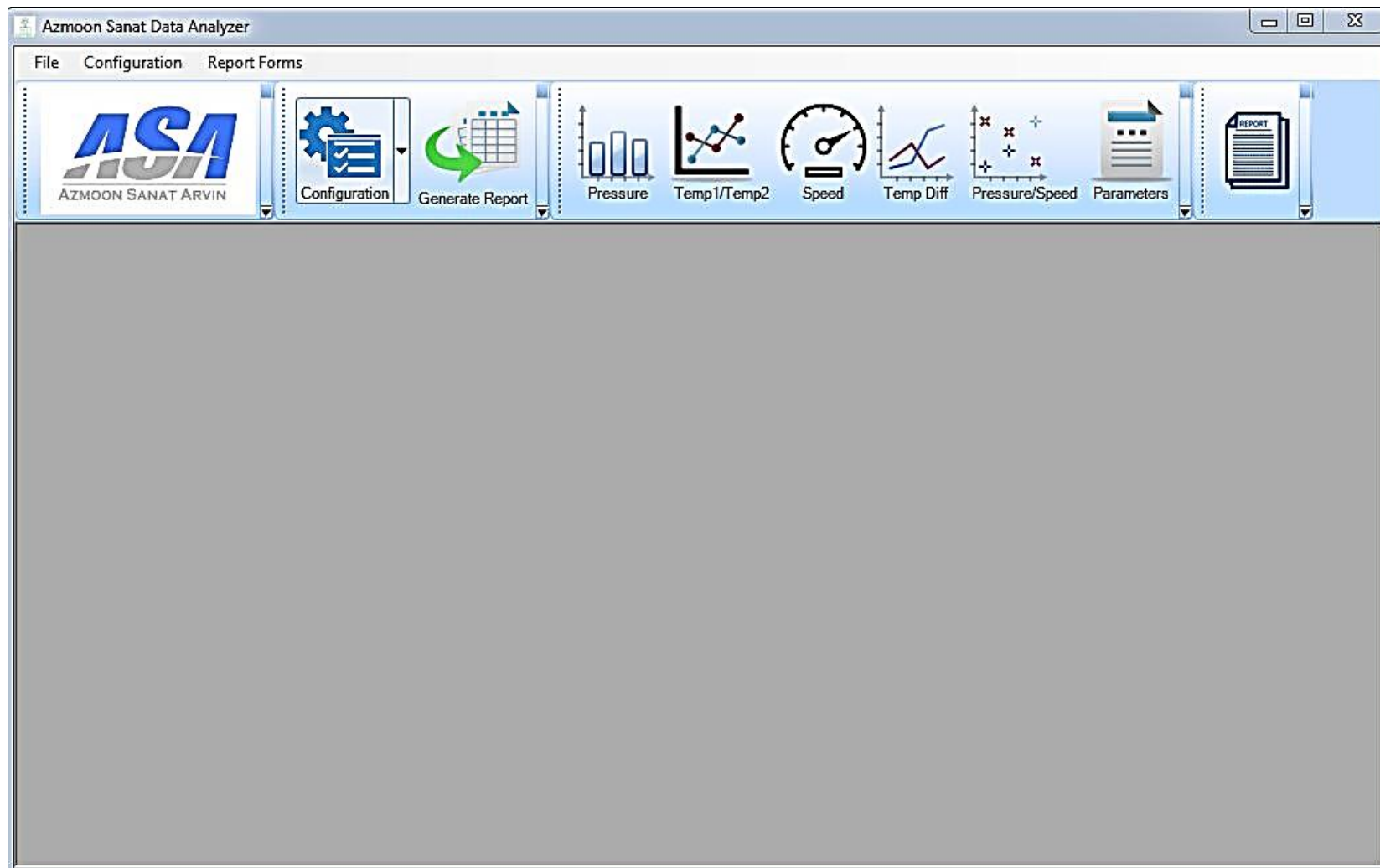
Sample #	Date	Result
1	2014-Nov.	2.29
2	2014-Dec.	2.3
3	2015-Jan.	2.31

## **Experiences from Retrofit Activities in Tehran / Case Study**

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### **Project Documentation and Data Management**

# ASA Data Analyzer (Evaluating engine operational parameters)



# ASA Data Analyzer's Feature

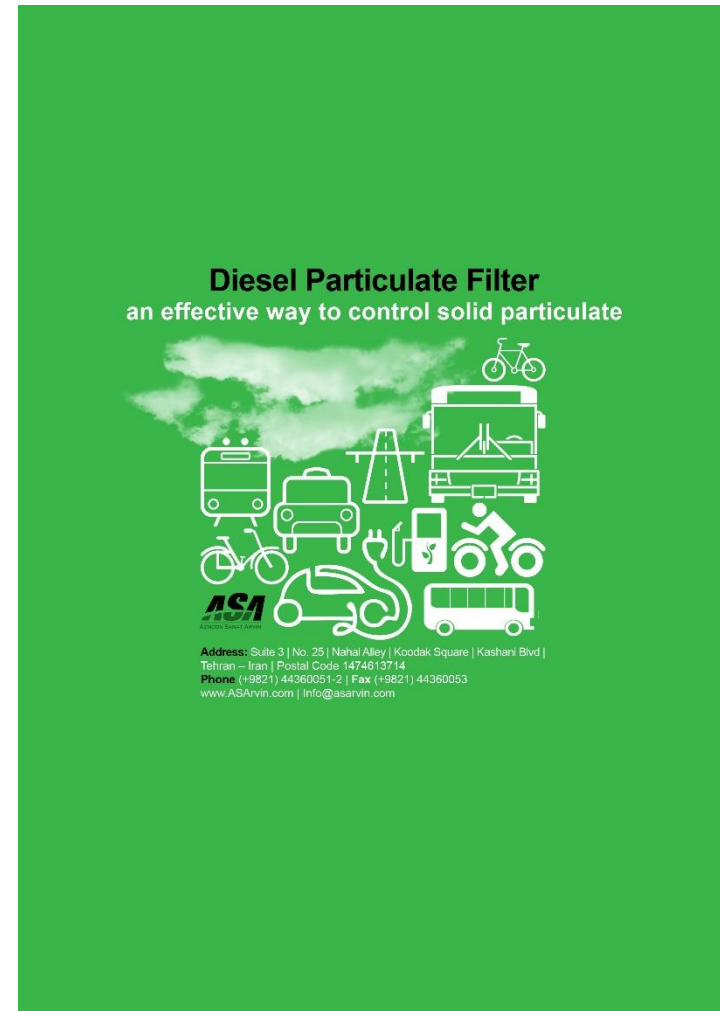
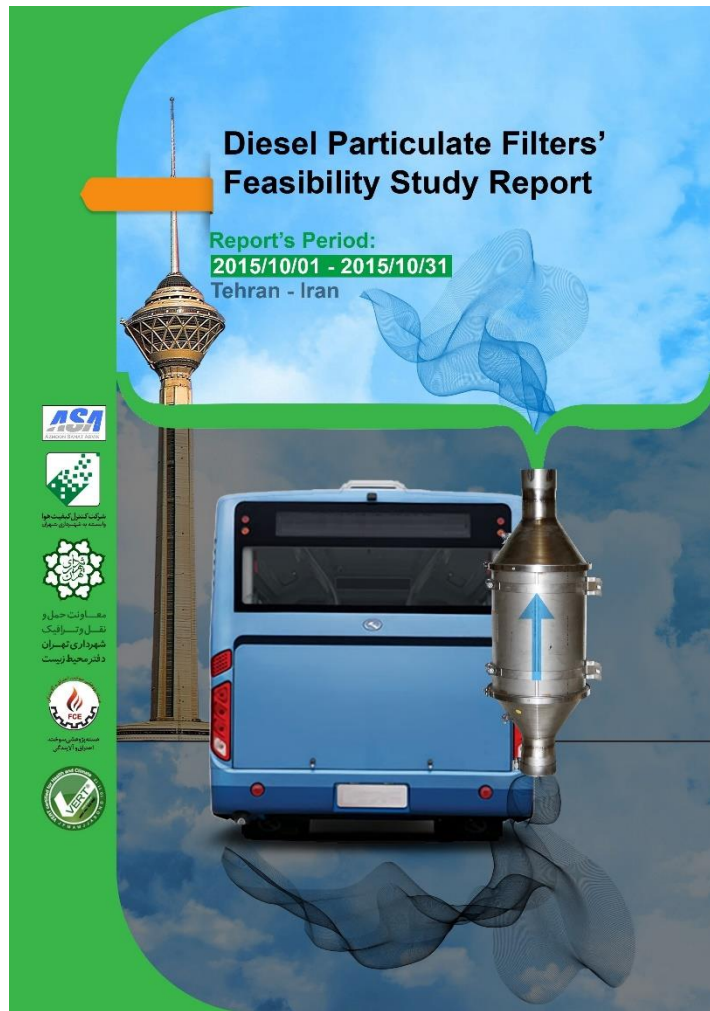
- Analytical charts for exhaust gas temperature
- Analytical charts for backpressure
- Analytical charts for rotational engine speed
- Calculating vehicle working hours
- Calculating idle working
- Fuel, additive, oil consumption
- Providing complete report as word file

(all above-mentioned information)

*Video (hyperlink)*

# Regular Monthly Reports

- Collecting DPFs' detailed information in the monthly reports



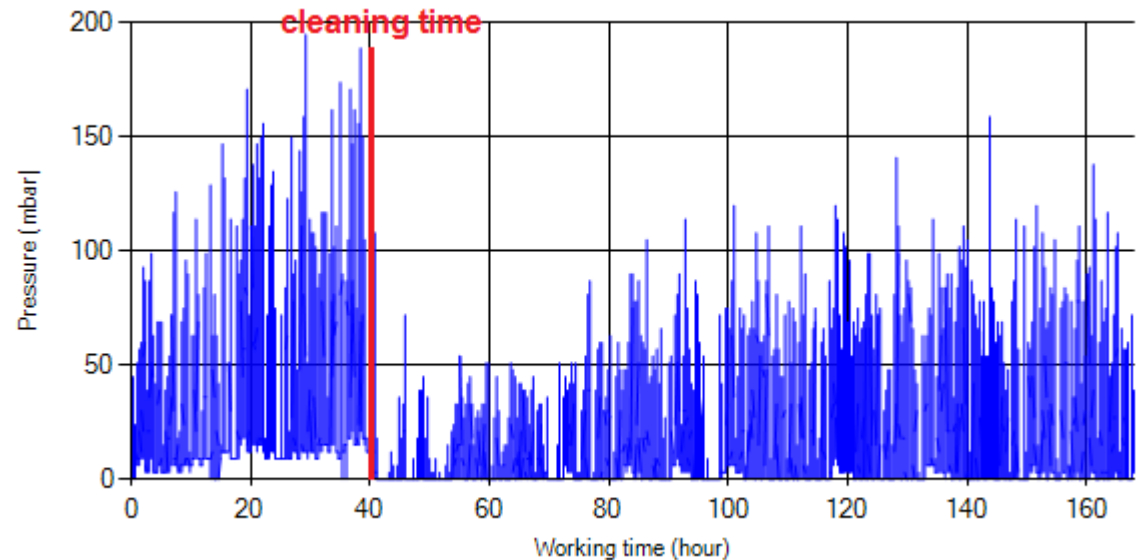
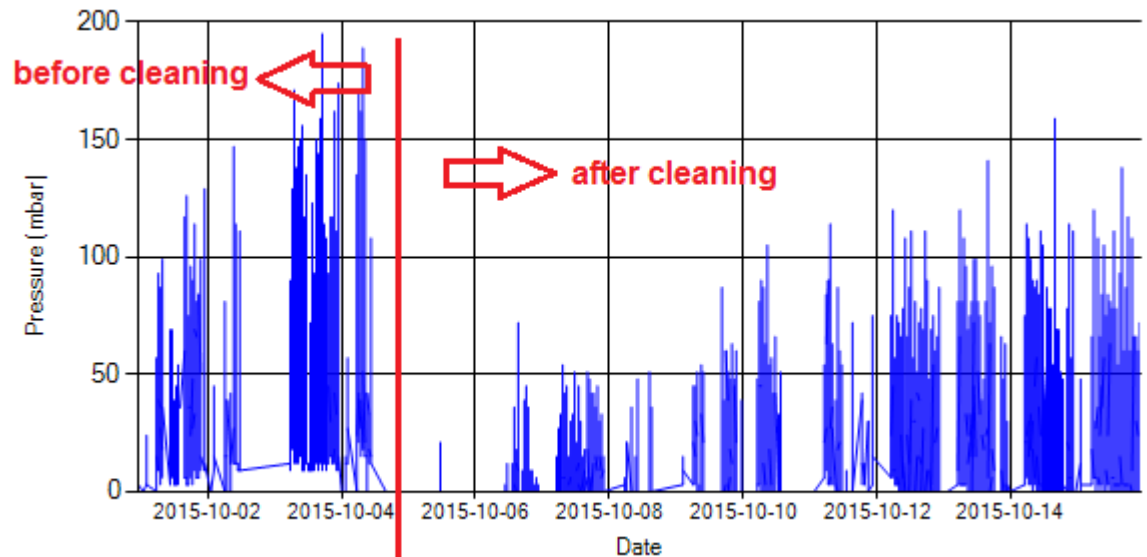


# Sample of Decision Making Based on Back Pressure Analysis

- ❑ 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% (P200~0)
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**

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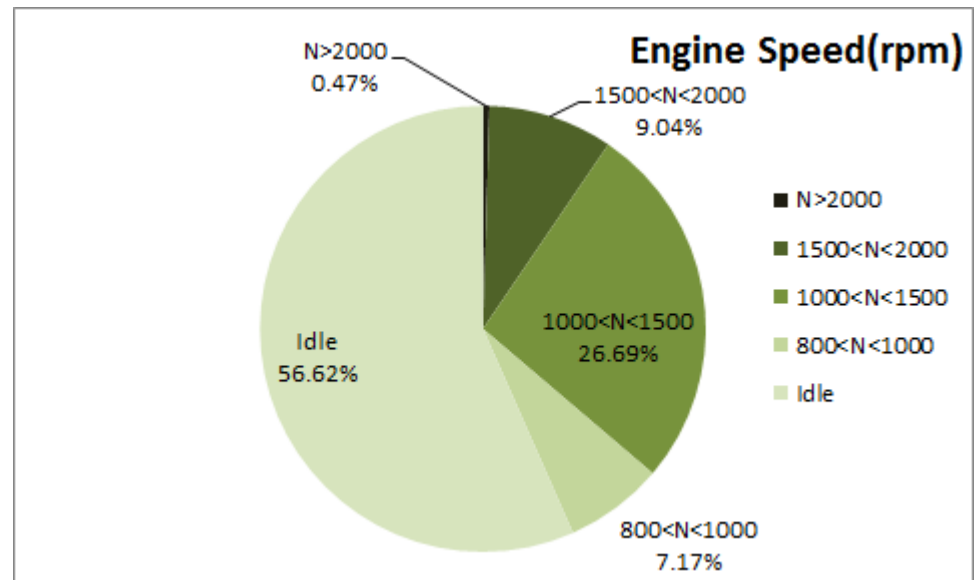
### **Driving and Maintenance Culture**

# 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?

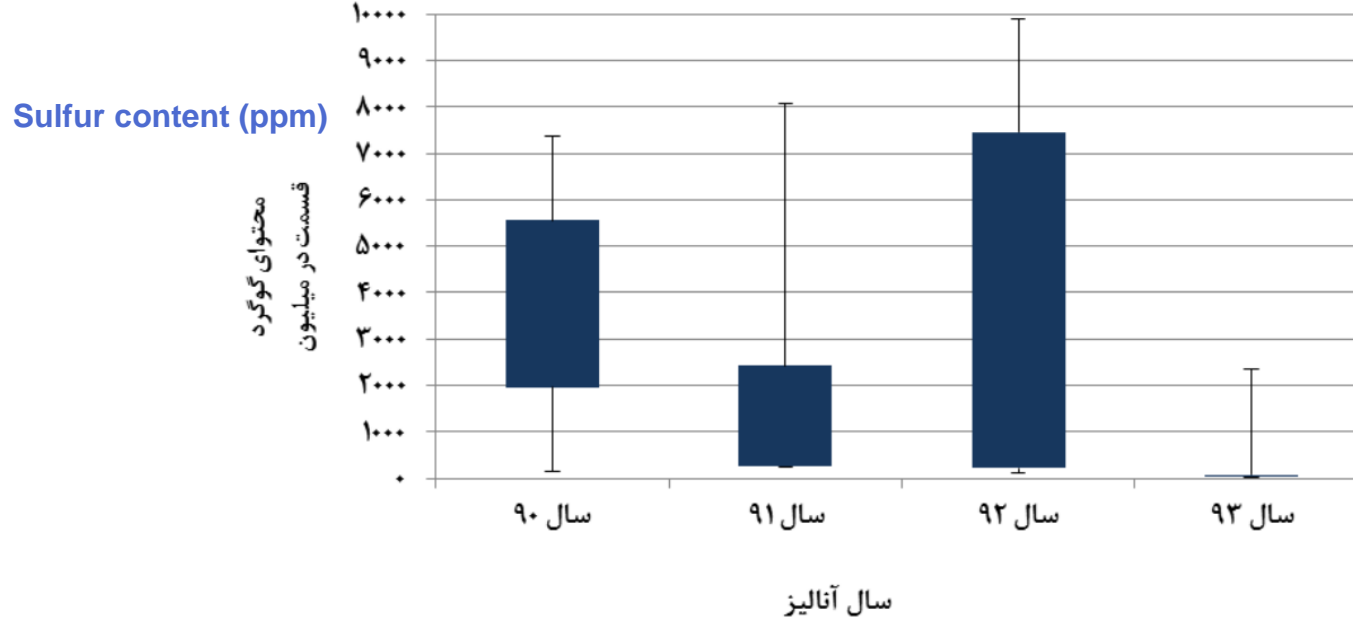
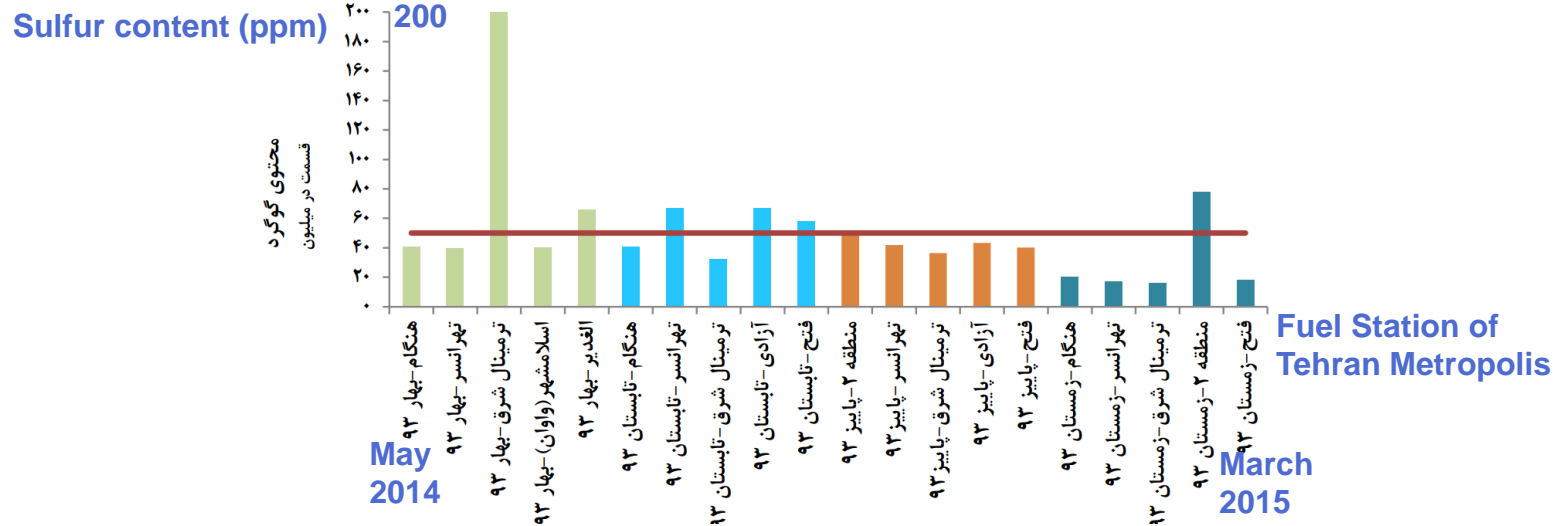
1. Training and raising awareness of high idling risk
2. Installation of on-line data loggers plus central data processing → automatic warning or
3. DPF's ECU data downloading and processing regularly

## Experiences from Retrofit Activities in Tehran / Learning Issues

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**Fuel Quality**

# Drastic Fuel Quality Improvement



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 1394-QM94/02/01/(U)/01 - تیر 1394

## Experiences from Retrofit Activities in Tehran / Learning Issues

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### 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
<b>Working Line</b>		Line 10- South to North Line		Line 2 – West to East Line		Line 4 – South to North Line			
<b>Working Days</b>		316	50	320	21	480	371	273	325
<b>Mileage (km)</b>		49,700	8,000	42,800	2,500	75,000	47,550	38,000	55,500
<b>First cleaning</b>	mileage	23,644	-	30,800		36,000	13,253	26,500	-
	comment	-	low working days	-	3 times cleaning	-	Doesing system was not adjust	-	-
<b>Second cleaning</b>	mileage	43,700	-	-		-	-	few thousands	-
	comment	-	-	-	not suitable for low temp. line	-	-	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):  $< 600$  °C
- ❑ Price: ?!

# Passive - CDPF

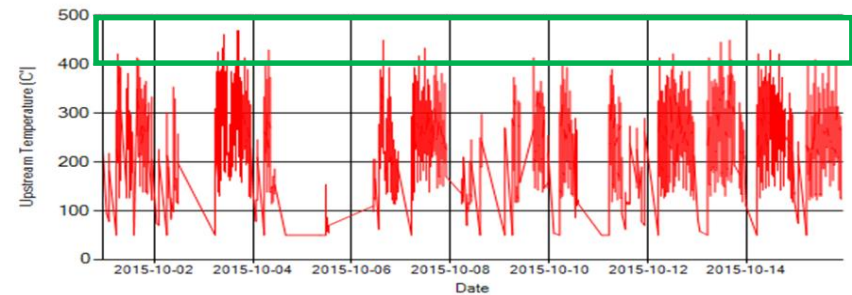
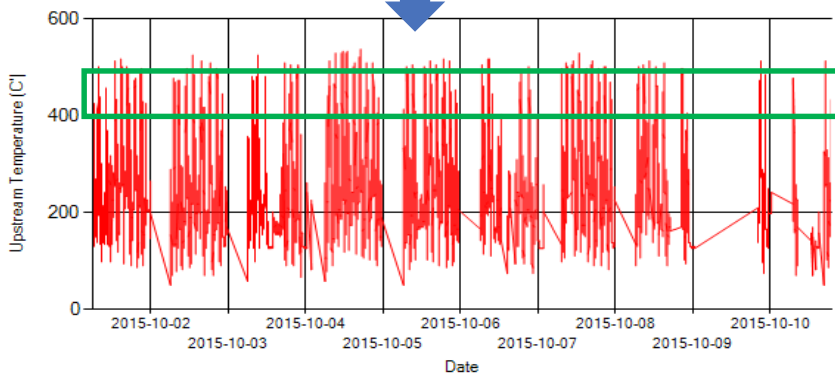
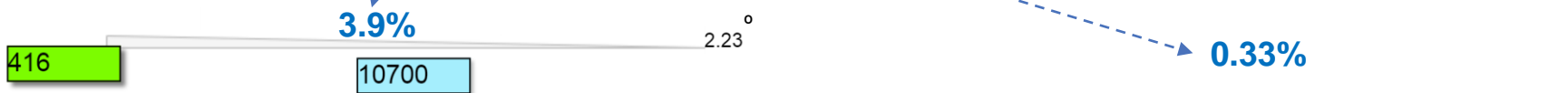
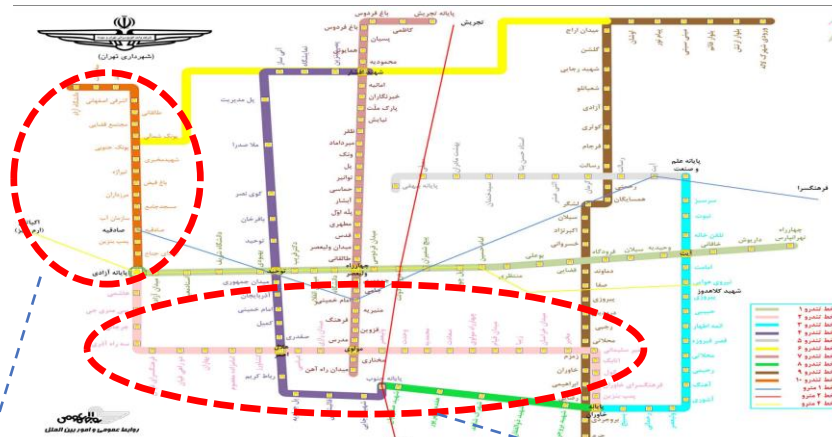
- Compatibility with high sulfur fuel: passed 230 ppm
- Mileage : 8000 km ( 50 days )
- Back pressure since installation: 110 to 120 mbar
- Maximum detected temperature (safety issue): 450 °C
- Price: ?

## Experiences from Retrofit Activities in Tehran / Learning Issues

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### Fleet Management

# Unique Geographical Conditions of Tehran

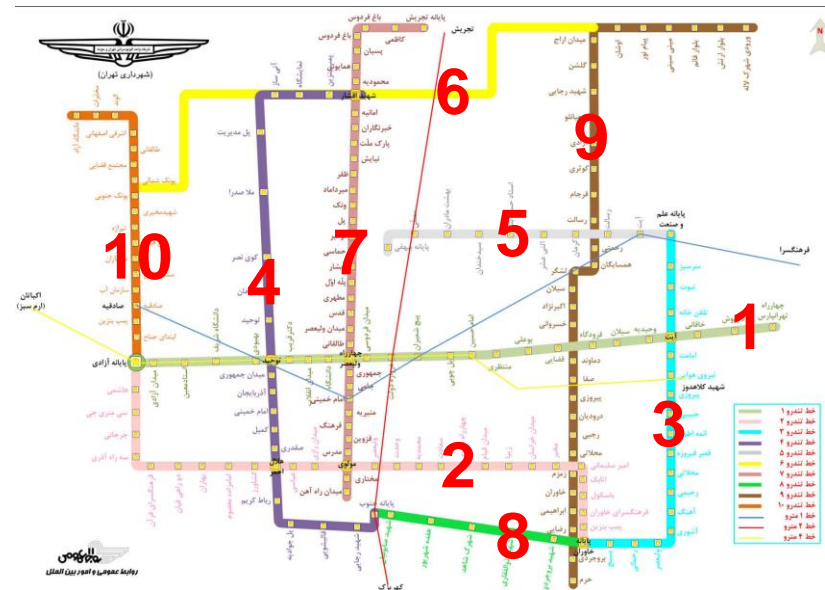


# Two Group Lines and Two Types of DPF

- ✓ 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



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