The road to developing performance standards for low cost sensors in Europe

Part2: application to the CEN TC 264 WG 42 protocol for low cost sensors

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Workshop Deliberating Performance Targets for Air Quality Sensors
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European Commission

Technical Specification for Sensors

-**Main question**: can low-cost sensors meet prescribed data quality objectives of the European Air Quality Directive

-**Expected result**: a protocol describing specific performance requirements and test methods under prescribed laboratory and field conditions

Technical Specification for Sensors

The TS on air quality sensors is split into two parts "Air quality – Performance evaluation of air quality sensors":

-**Part 1**: Gaseous pollutants in ambient air for O_3, NO_2 and NO, CO, SO_2, benzene and CO_2.

-**Part 2**: Particulate matter in ambient air (NWI proposal should be prepared) for PM10 and PM2.5.

Technologies considered in the protocol

-**PM_{10} and $PM_{2.5}$**: Laser based particle counter and nephelometer.

-**O_3, NO_2, NO, CO and SO_2**: electrochemical sensors (potentiometric and amperometric), metal oxide sensors (SnO2, WO3 …).

-**CO and CO_2**: Infra-red cells.

-**Benzene and other VOCs**: MOx, FID, mini GCs.

CEN WG 42 Technical Specification

3 sensor categ… …lity Directive

Class 1 se…

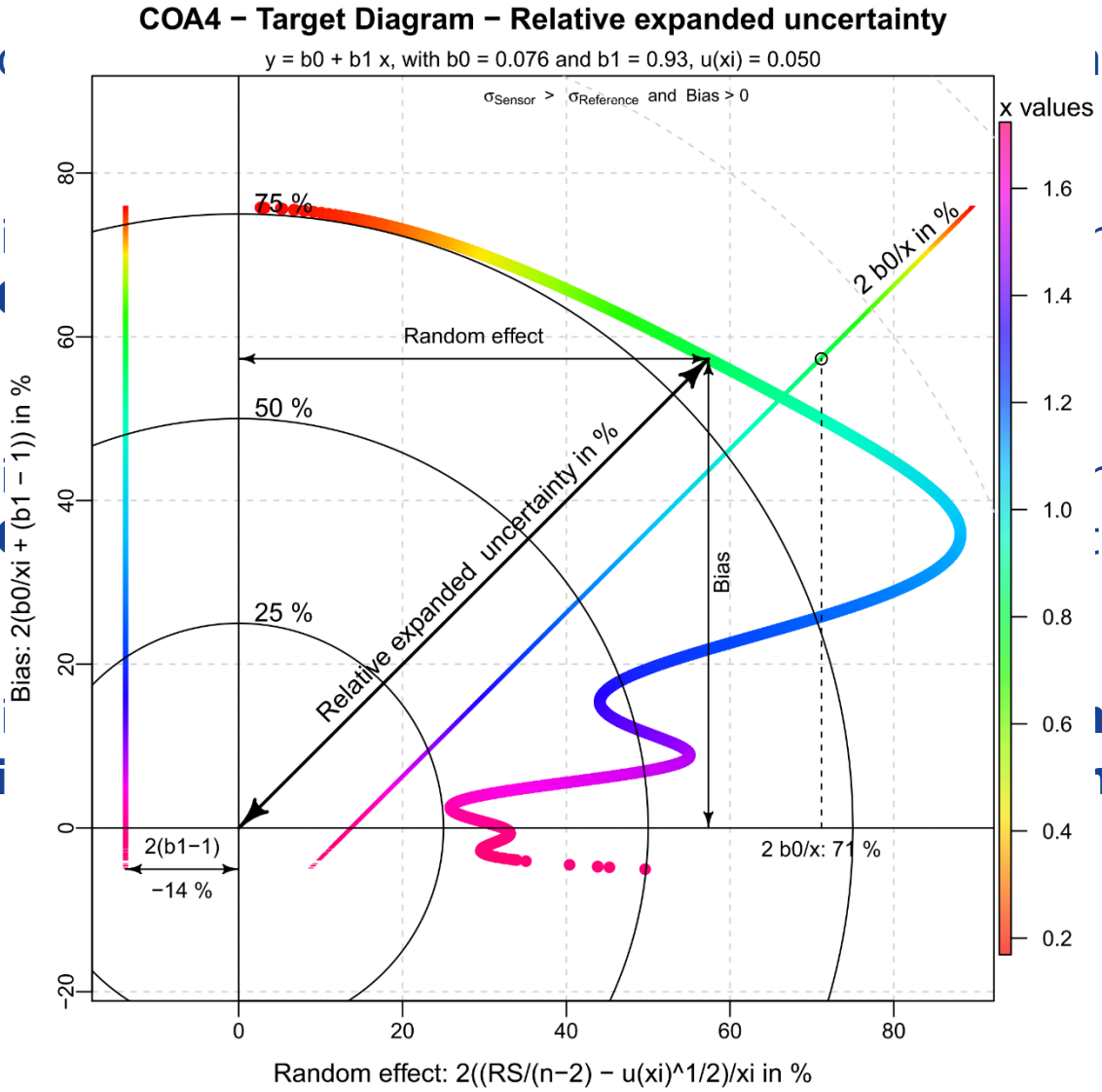
measuring devi… …nt with the **Data Quality …** …AQD

Class 2 se…

measuring devi… …nt with the **Data Quality …** …he AQD

Class 3 se…

measuring devi… …**nally associated wi… …ncertainty**



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Technical Specification for sensors - method

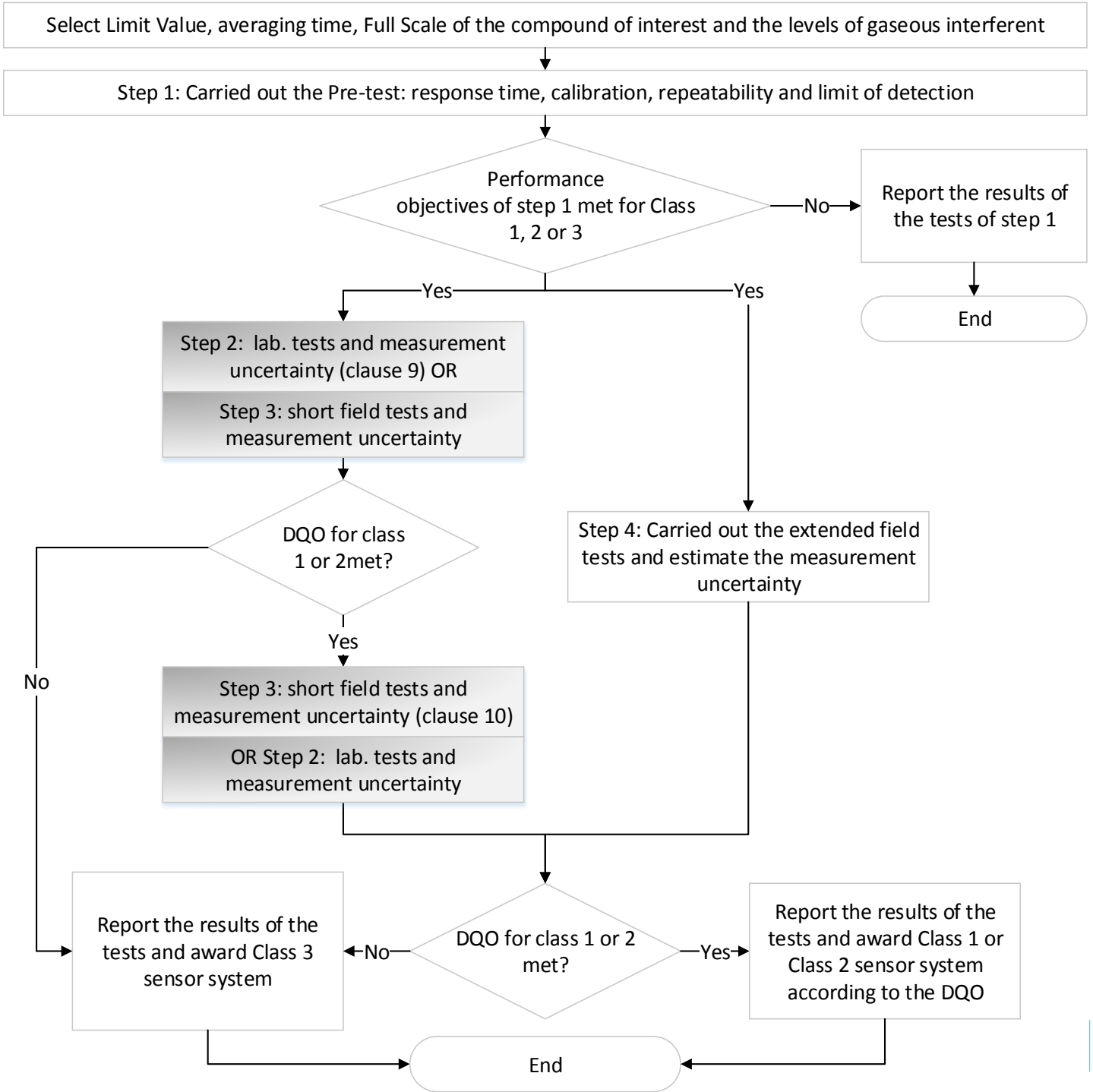
Gas sensors:

- A lab. pre-test is required to check linearity, response time and limit of detection
- Two routes are feasible for the classification of sensors:
  - perform a list of laboratory tests in exposure chamber using synthetic gas mixture plus a short field test programme
  - or only perform an extended field test programme

PM sensors:

- Check flow rate, effect of temperature and power supply in lab.
- Perform an extended field test programme.

The field tests of gas and PM sensors are evaluated with the method of the "Guide for the Demonstration of Equivalence". More stringent performance criteria for the best class.


Select Limit Value, averaging time, Full Scale of the compound of interest and the levels of gaseous interferent
Step 1: Carried out the Pre-test: response time, calibration, repeatability and limit of detection
Performance objectives of step 1 met for Class 1, 2 or 3
No
Report the results of the tests of step 1
End
Yes
Yes
Step 2: lab. tests and measurement uncertainty (clause 9) OR
Step 3: short field tests and measurement uncertainty
DQO for class 1 or 2met?
Step 4: Carried out the extended field tests and estimate the measurement uncertainty
Yes
No
Step 3: short field tests and measurement uncertainty (clause 10)
OR Step 2: lab. tests and measurement uncertainty
Report the results of the tests and award Class 3 sensor system
No
DQO for class 1 or 2 met?
Yes
Report the results of the tests and award Class 1 or Class 2 sensor system according to the DQO
End

Data Quality Objective – Air Quality Direct.

	Averaging time	LV	DQO of Class 1 sensor system	DQO of Class 2 sensor system
	(h / year)	(µg/m³)		
SO2	1 h	350	87.5 (25 %)	262.5 (75 %)
SO2	24 h	125	31.3 (25 %)	93.8 (75 %)
NO2	1 h	200	50 (25 %)	150 (75 %)
NO2	1year	40	10 (25 %)	30 (75 %)
NOx	1year			
CO (mg/m³)	8 h	10	2.5 (25 %)	7.5 (75 %)
O3	8 h	120*	36 (30 %)	90 (75 %)
O3	1 h			
Benzene	1 year	5	1.5 (30 %)	5 (100 %)

Tests to be performed for the evaluation of sensors in laboratory or at field sites	Class 1	Class 2	Class 3
1: Response time	Lab.	Lab.	Lab.
1: Calibration	Lab.	Lab.	Lab.
1: Repeatability, limit of detection	Lab.	Lab.	Lab.
2: Short and long term drifts	Lab. or Field	Lab. or Field	
2: Cross sensitivities by gaseous interfering compounds	Lab.	Lab.	
2: Humidity effect	Lab.	Lab.	
2: Temperature effect	Lab.	Lab.	
2: Hysteresis of sensor for the main pollutant	Lab.	Lab.	
2: Hysteresis effect when changing the level of temperature and humidity	Lab.	Lab.	
2: Transient effects of rapid change of humidity (chemical sensors only)	Field	Field	
2: Wind velocity effect (informative)	Lab.	Lab.	
2: Pressure effect. This test is mandatory for sensor based on IR (informative)	Lab.	Lab.	
2: Electromagnetic fields (informative)	Field	Field	
2: Power supply (informative)	Lab.	Lab.	
3 and 4: short or extended field	Lab. or field	Lab. or field	Lab. or field

Examples of performance requirements

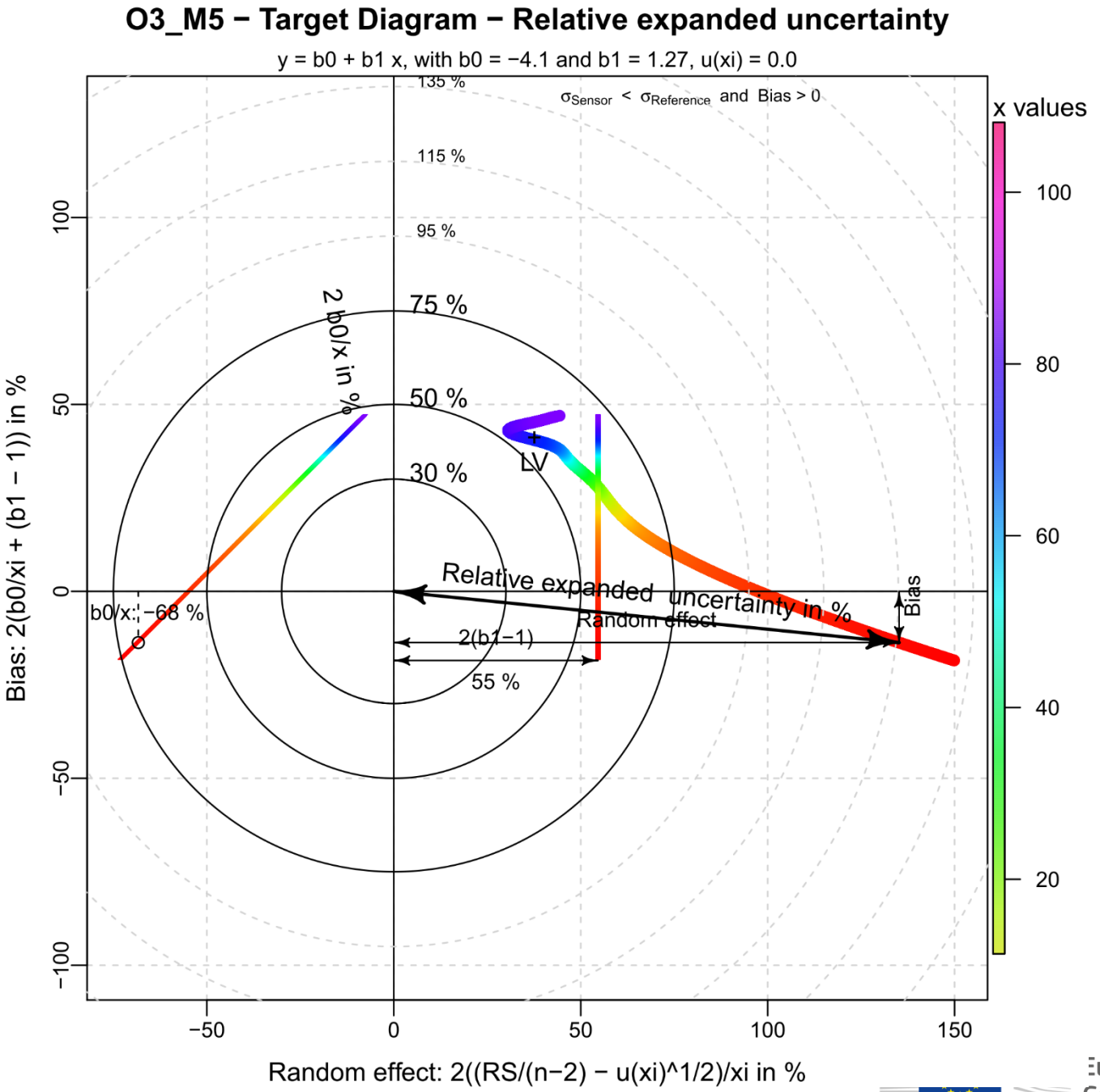
Steps			Class 1 sensor systems	Class 2 sensor systems	Class 3 sensor systems
1	Response time		t_{90} < 1/10 of averaging time (generally 1h) at traffic site or t_{90}< 1/3 of averaging time (generally 1h) at background sites	t_{90}< 1/4 of averaging time (generally 1h) at background sites	t_{90}< 1/4 of averaging time (generally 1h) at background sites
1	Calibration		U(lof) < 8 %	U(lof) < 12 %	U(lof) < 12 %
1	Repeatability (r), limit of detection (LOD)	O3, NO, …	r ≤ 8.0, LOD ≤ 20 µg/m³ r ≤ 5.0, LOD ≤ 12.5 µg/m³ …	r ≤ 12, LOD ≤ 30 µg/m³ r ≤ 7.5, LOD ≤ 18.7 µg/m³ …	r ≤ 12, LOD ≤ 30 µg/m³ r ≤ 7.5, LOD ≤ 18.7 µg/m³ …

Data Quality Objective – Air Quality Direct.

	Averaging time
Parameters	Standard uncertainties
lack of fit of calibration function	u(lof)
Long term drift	$u(D_{LD})$
Temperature effect	$u(X_T)$
Humidity Effect	$u(X_{RH})$
Cross sensitivities from gaseous interferents	u(int)
Hysteresis of the test gas	$u(h_X)$
Hysteresis of humidity	$u(h_{XRH})$
Hysteresis of temperature	$u(h_{XT})$
Pressure effect	$u(X_P)$

Number of field sites

Compound	Areas			Sit		Short field test	Extended field test
	Urban	Suburban	Rural	Traffic	Background	Total number of sites	Total number of sites
NO2	+	+		+	+	4	8
NO	+	+		+	+	4	8
O3	+		+		+	2	4
CO	+			+	+	2	4
SO2	+				+	1	2
Benzene	+			+		1	2
CO2			+		+	1	2



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Unresolved issues

- Difficult to find an agreement/equilibria between the costs of testing and the need of sensor evaluation reflecting all gas composition and meteo conditions found in EU.
- Number of field extended tests when the full list of laboratory tests is not performed: current proposal is 12 sites for class 1 and 6 sites for class 2 gas sensors. The WG is looking for possibility to decrease these numbers.
- For PM sensors: difficult to implement the flow stability, leak test, temperature and power supply drift tests with low-cost PM sensors.
- It seems contradictory to require more tests for PM low-cost sensors than for AMS as requested in EN 16450

Unresolved issue

- Results of evaluation studies are needed for drafting the TS, avoiding setting unrealistic test conditions and performance criteria for O3, NO2, NO, CO, CO_2, SO_2 and PM sensors

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