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INSTRUMENTED IN-USE-VEHICLES, A VERSATILE TOOL TO MEASURE EMISSIONS

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ABSTRACT

Emission data and resulting emission factors from mobile sources provide indispensable parameters for decision making on regional air quality control.
Such data, if sourced “from other cities”, usually disqualify as being too coarse as they do not reflect the local mix of vehicles, fuel and service quality and driving behavior.

The paper describes a technology to instrument vehicles for accurate and cost- efficient acquisition of in-use motor vehicle emission data, while driving on the road. This includes a newly available on-board mobile/ portable emission measuring system, focusing on application in buses and trucks.
Until recently, such data could only be obtained with the help of laboratories equipped with complex and costly emission chassis dynos. As such facilities rarely exist for heavy-duty vehicles, these major sources of air pollution are often excluded.
Despite it’s small size and low power consumption, the new system uses laboratory-grade analyzers with inbuilt calibration gases. It delivers accurate values of emission mass as required by the legislation.
The new tool will not only close some gaps in scientific work but will also empower local authorities to better manage and verify regional air- pollution reduction undertakings.

Key Words: Real World Emissions, Emissions Factors, On Board Emissions Testing; Air Polution Models; Mobile Emission Measurement Systems (MEMS)

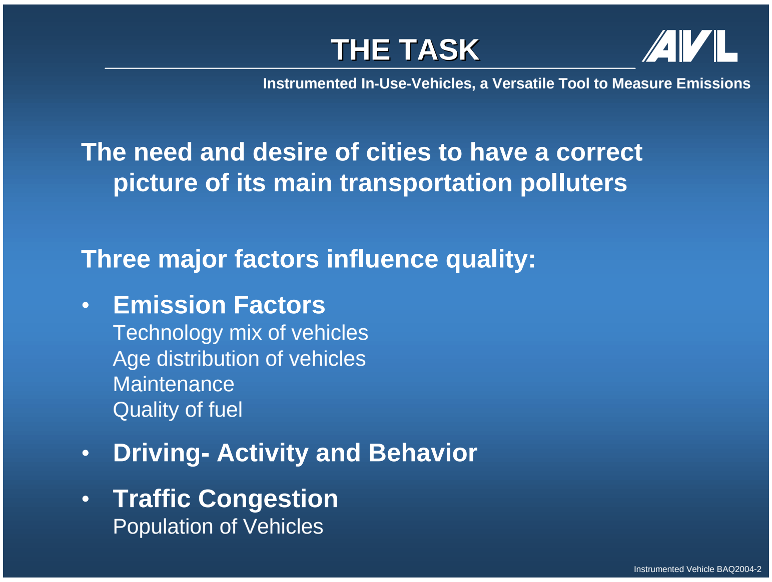
1. INTRODUCTION

It is an ongoing dream of the test engineers to take measurements in-situ rather than taking the test object to a laboratory. This is even more true when it comes to the test of bulky objects such as a great number of different vehicles under the various driving conditions of a complex city.
Advances in electronics, computerization and remote positioning now make it possible to perform ”laboratory grade” measurements of mass emissions (g/km or g/h) with mobile systems operated in the driving vehicle.
This paper reports on this new solution.

2. THE TASK

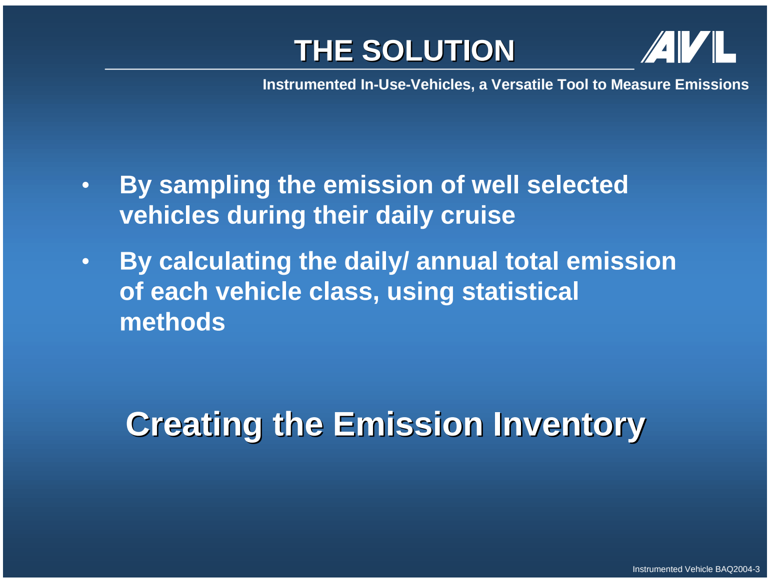
Environmentalists, city and traffic planners need to know where, when and under what conditions the flowing traffic contributes to the overall pollution of a given city.

Ideally current data can be compared with future data by using alternative prediction models- some of which can be tested and evaluated at present by applying improved vehicle technology and better fuels.



3. THE TASK

As with all statistical methods the overall results improve significantly with the number of samples and the accuracy of its measurement.
There is however a trade off between cost of sampling and quality needed.
Starting with a coarse first overview followed by selected in-depth sampling usually offers optimized cost/ quality relations of good emission inventories

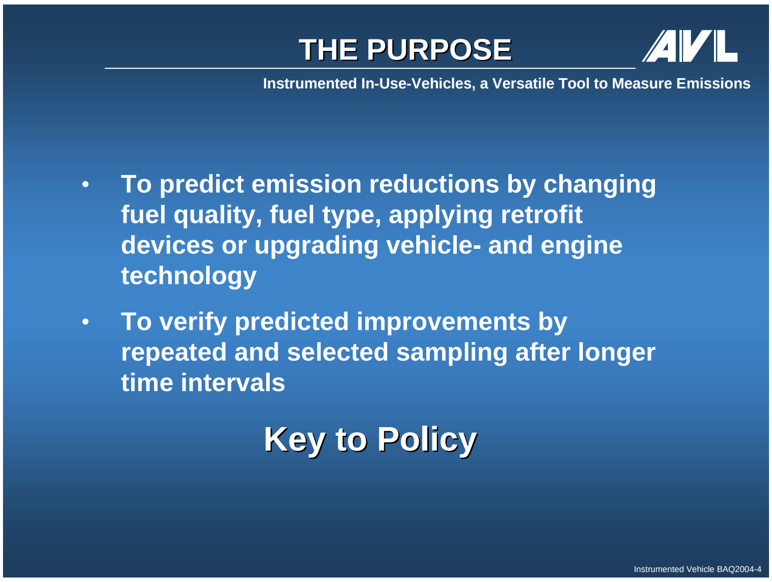


4. THE PURPOSE

Changing and improving the traffic system of a city is a cost intensive and has long lasting implications to many sectors.

It is therefore imperative for the legislator to have on hand best possible data of the presence and trustworthy predictions for the future.

To ensure sustainable improvements data validation with equal methods throughout the time line is required in addition.



5. THE ALTERNATIVES

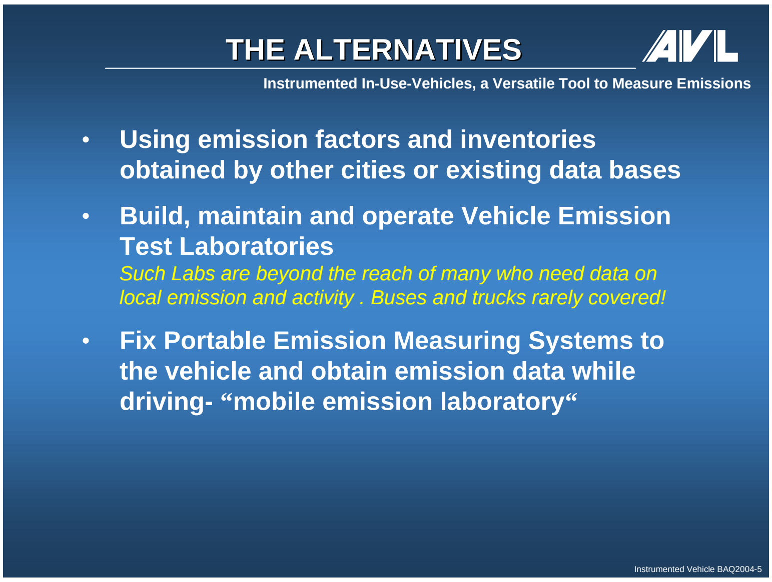
For a start using emission inventories on traffic from other cities might be helpful. Inventories from cities in Industrialized countries will however provide wrong picture as technology and legislative are advanced.

Inventories from Asian cities (such as Bangkok or Shanghai) will offer more useful data in future.

Few cities have access to fully fledged emission test laboratories; even fewer have facilities allowing the testing of buses and trucks (PCD Bangkok).

This is still not much help to all ”the other” cities in the region.

The modern alternative thus is to pack a ”mobile emissions laboratory” to the sample vehicles- saving cost and gaining high flexibility



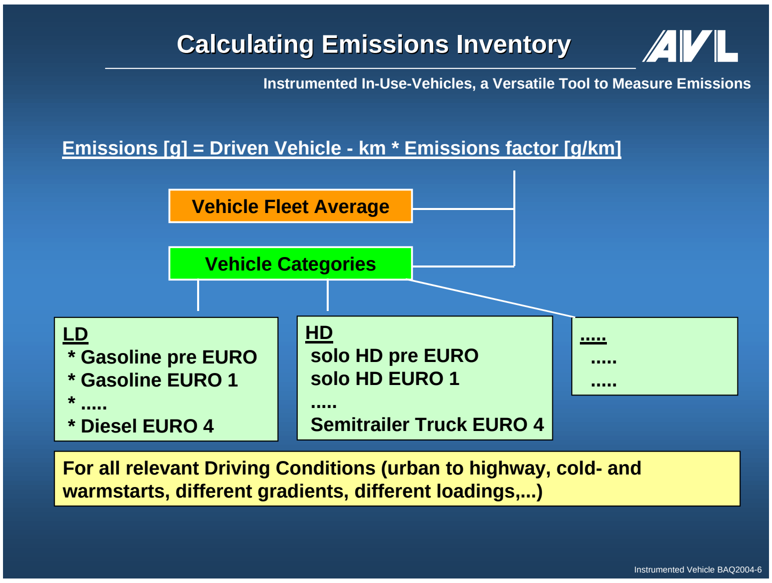
6. CALCULATING EMISSIONS INVENTORY

An emission inventory shall give the total emissions occurring in a defined area. Areas under consideration reach from single streets up to total countries. All used models have the same simple approach where the total emissions are calculated from:

with E.......total emissions in the area [e.g. g per day]
v-km.........total vehicle mileage [e.g. km per day]
e...............emission factor [g/km]

Most simulation tools used for emission monitoring are global emission and inventory models. Such models are usually based on traffic statistics and measured “emission factors” where an emission factor gives the emission value e.g. in [g/km] for a defined vehicle category in a defined traffic situation. The definition of the “average” driving cycles for a traffic situation has a high influence on the resulting emission factors. Since vehicles are driven in cold and hot running conditions, uphill and downhill, empty and full loaded in situations from congestion to free flowing traffic and with drivers having very different driving styles, a huge variety of potential using patterns exist.

As a result it is very difficult to define which driving situations are “relevant” for the air quality. Certainly all driving situations in which the most vehicle kilometer's are driven are relevant, e.g. highway driving with an average volume of traffic per lane.
E.g. a total of 10 % of driving situations which have 200 % higher emission levels than the average will already give them 25 % of the total emissions (Hausberger, 2003).



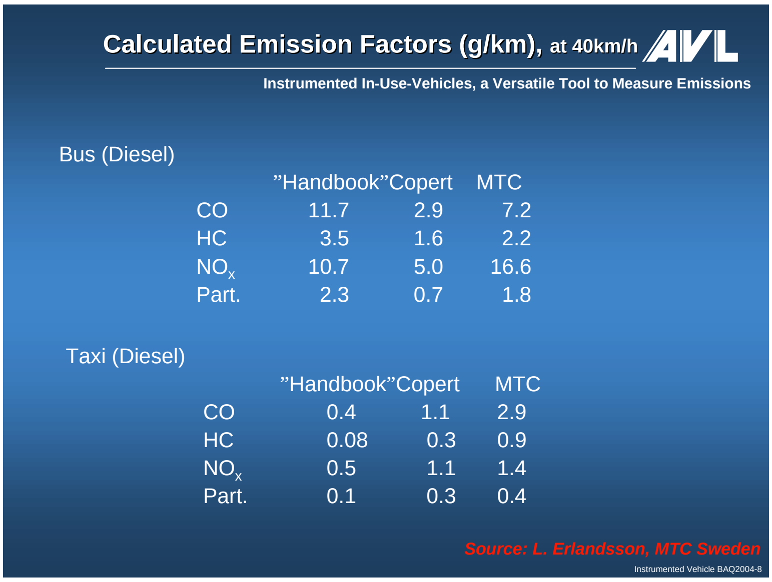
7. STEPS TO MORE ACCURATE INVENTORIES

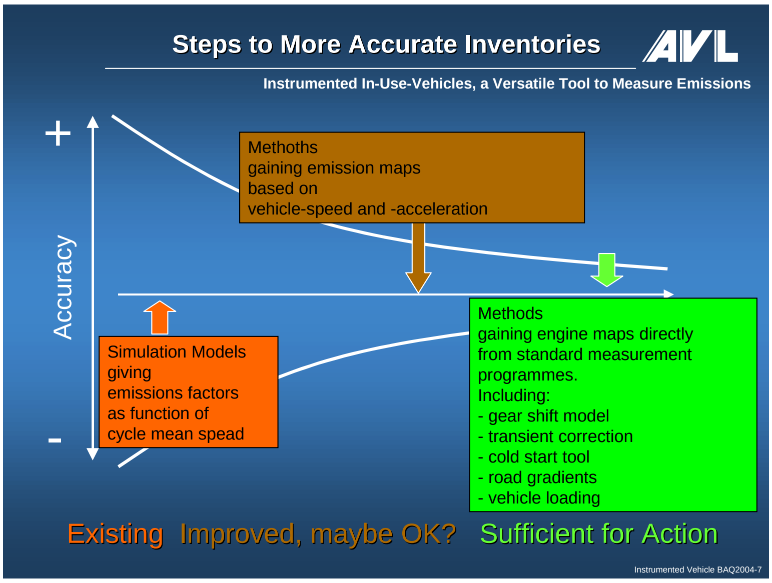
Existing Data Basis:

USA:
Mobile 5/5b, Mobile 6
Europe:
COPERT III; “German Handbook”; Artemis (not finalized)

Beside their inaccuracy the main drawback of the 2 methods shown on left in the following slide is that they can not simulate “non standard” driving cycles sufficiently. Such cycles include different gear shift behaviours, road gradients, vehicle loadings and the usage of energy intensive auxiliaries like air conditioning. All of these “non standard” situations potentially have high effects on the emission levels

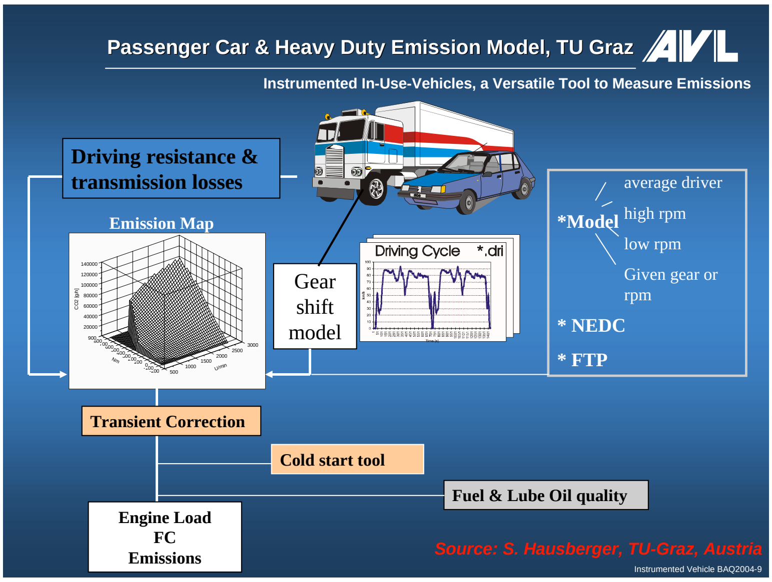
Especially on HDV the influence of vehicle loading and road gradients has a very important effect.





8. COMPARISON OF COMMON MODELS

In the slide below Emission Factors with three different models are generated and compared.



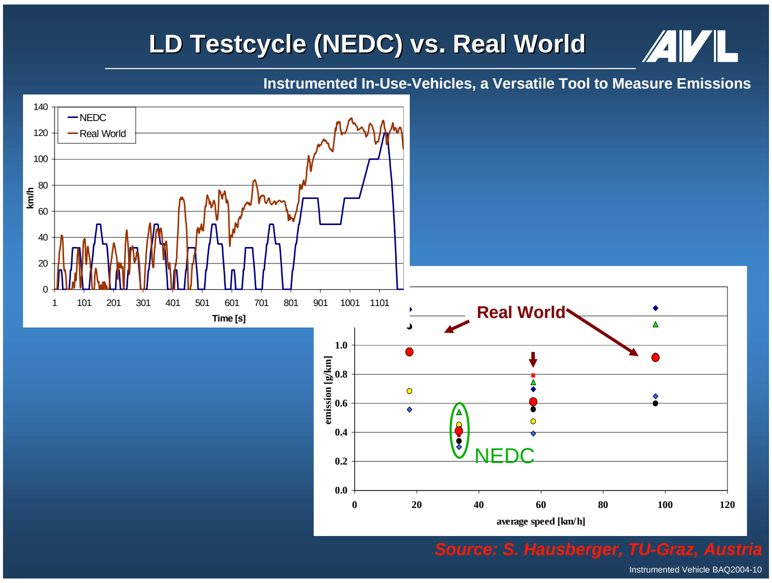
The wealth of local factors as described affecting emissions are weighed to form the final factor
There is no single "method" to design an emission factor
Verification is essential (by the use of local emission laboratory and the help of new methods like PEMS)

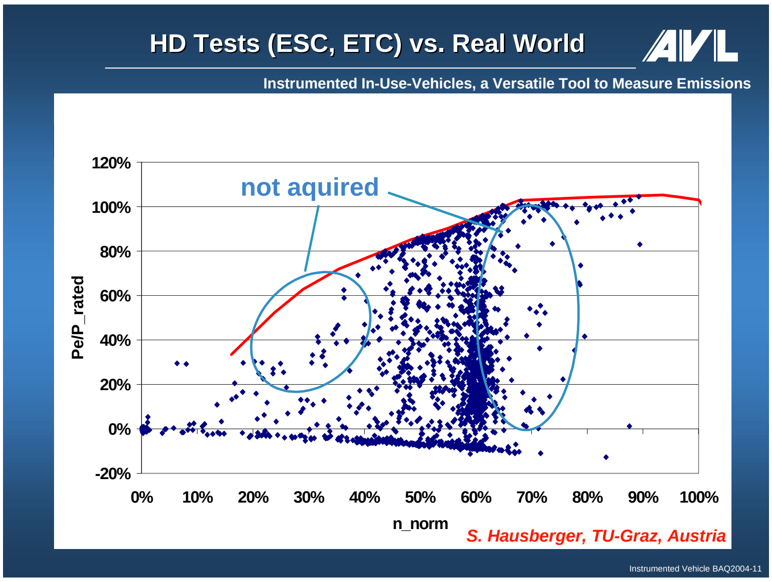
9. EXAMPLE FOR A EMISSION MODEL

With a given driving cycle and road gradient the effective engine power is calculated in 1Hz frequency from the driving resistances and losses in the transmission system. The actual engine speed is simulated by the transmission ratios and a drivers gear shift model. The emissions are then interpolated from engine maps. Basically this method is capable of simulating the fuel consumption and the emissions for any driving cycle with any vehicle configuration.
All models described use a lot of emission measurements as model input and most of them use the data for model validation as well.
Measurements of fuel consumption and emissions are usually performed on roller test benches, engine test beds or on-board at the vehicle. Test beds have the advantage of exactly defined boundary conditions and thus a good repeatability. On-board measurements can be performed in real world traffic which allow an easy and exact recording on the road.

10. TEST CYCLE EMISSION VERSUS REAL WORLD EMISSION

The slide below shows the speed distribution of the New European Driving Cycle (NEDC), driven on a chassis dyno for Light Duty Vehicle. Additional to this legislative Cycle a “Real World Cycle”, which was recorded in real traffic, is shown. It is visible, that the real world cycle is more dynamic than the the NEDC and that the cycle mean velocity is higher. According to this the real world emissions can be higher than we expect it from the legislative measurements

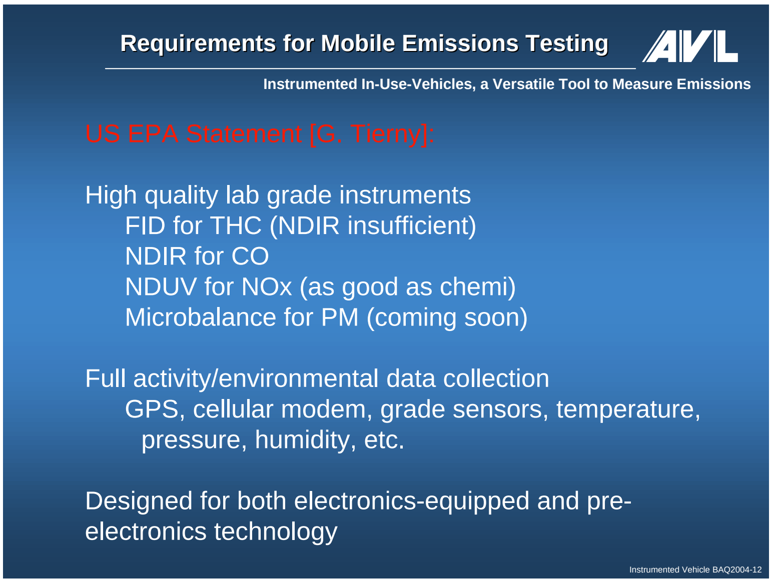




The investigation of HDV emissions in real world driving behavior shows us that since the introduction of the EURO 1 limits the emission levels have not decreased in real world driving conditions to the same extent as the emission limits for the type approval have been reduced. Main reasons are found in the more sophisticated technologies for engine control and fuel injection. On the one hand these modern technologies are a prerequisite for reducing the environmental impacts of HDV engines, on the other hand they give freedom for different specific optimizations at different regions of the engine map. Since fuel costs are a main factor for the competitiveness of HDV engines, manufacturers optimize the engines towards high fuel efficiencies wherever possible. That affects especially the NO^x emission levels. The steady state tests at the type approval can thus not ensure low emission levels for real world driving conditions. This was mainly found for EURO 2 engines tested with the R 49 steady state cycle while the European Stationary Cycle (ESC) valid for EURO 3 engines improves the situation. But still a broad range of the engine map is not controlled sufficiently.

11. REQUIREMENT FOR MOBILE EMISSION TESTING

Cause of the demand to measure and audit Real World Emissions US Environmental Protection Agency founded a initiative to develop Mobile Emission Measurement Systems (MEMS) with the following requirements.

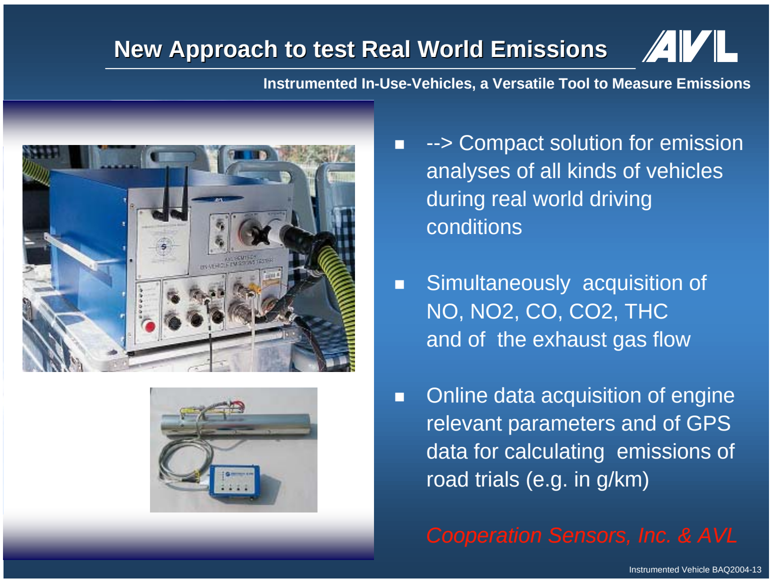


The contribution of transport to air pollution is of major concern in Europe. The member states of the European Union need efficient policy monitoring tools to check the in-use conformity of road vehicles with the emissions standards. The extraction of engines from heavy-duty vehicles or heavy non-road machinery to compare pollutant emissions against legislative limits is for several reasons impractical. A new approach to in-use conformity checking is needed. Therefore, the European Commission, through DG ENTR, is proposing to develop a protocol for in-use conformity checking (IUC) of heavy-duty vehicles based on the use of Portable Emissions Measuring Systems (PEMS).

A similar approach is followed by the US-Environmental Protection Agency (US-EPA) who initiated a research into the use of portable systems as a tool for in-use conformity checking of vehicles and engines. Their proposed method for IUC shall be applicable to 2007 and later model years (heavy-duty and non-road) engines.

12. APPROACH TO TEST REAL WORLD EMISSIONS

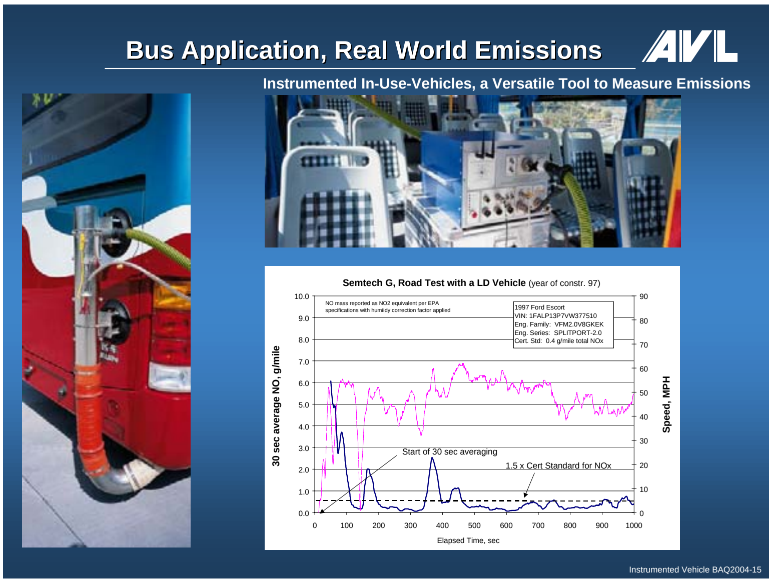
Cause of this need, AVL List GmbH of Graz and the analyzer specialist Sensors, Inc. of Saline, Michigan USA, have signed a Cooperation in august of 2004 to roll out a new tool and method of measuring "Real World Emissions"



The SEMTECH product line was developed in response to regulatory concerns that air quality has not improved despite the increased stringency in standards over the past several decades. Deploying technology which can gather vehicle emissions information from virtually all on- and off-road vehicles makes it useful for a variety of purposes, including:

- Development of realistic mobile emissions models
- Determining the effectiveness of after treatment devices
- Meeting passenger vehicles and trucks in use compliance and NTE requirements
- Detecting and solving driveability problems
- Certification and compliance of vehicle fleets
- Supplements dynamometer testing

The diagram below shows the real world Nox emissions as a function of the driving speed. The maxima of Nox are about 4 times higher than the legislative limits for this vehicle type.

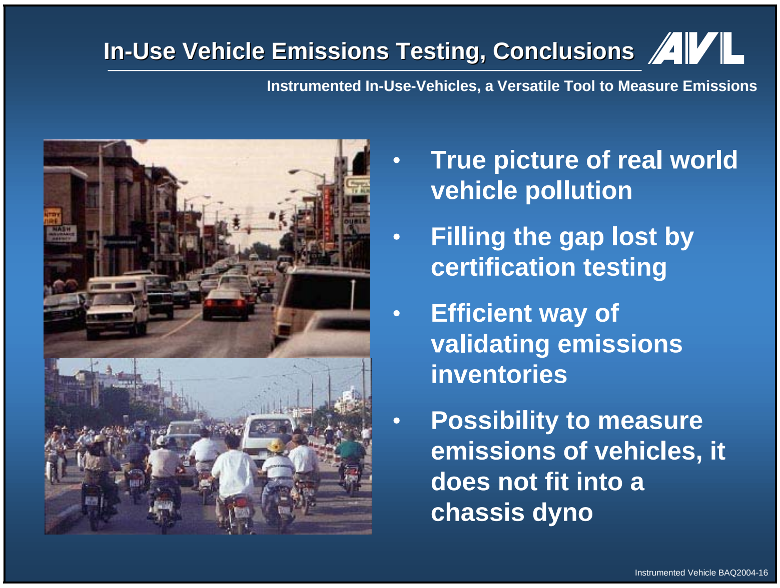


13. CONCLUSION

This paper presented a survey of methods for measuring and simulating vehicle emissions in real world driving conditions. As a result of the increased complexity of electronic engine control systems where the application has a high influence on the emission behaviour of the vehicles the established models become increasingly inaccurate.

Compared to traditional testing in emission test cells alone, on-vehicle, on-road emissions measurements using Mobile Emission Measurement Systems (MEMs) provide a broader and deeper understanding of how an engine and vehicle actually performs over its useful life. Regulatory agencies worldwide require laboratory based vehicle certification and subsequently most research to meet these requirements is carried out in emission test cells. Although remarkable improvements have been achieved this way, to make additional substantial improvements in vehicular emissions and over all air quality, it is necessary to supplement the traditional laboratory certification and research activities with in-use, on-road emission measurements using MEMs.

The accurate measurement of real world emissions levels is especially important for developing accurate emission inventories for future years and predicting effects of emission control strategies.



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