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How can we estimate today's and future particulate emissions from transport and air quality?

How can we estimate the future air quality?

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Abstract

Measurements are an important basis for risk assessments, e.g. resulting from exhaust pollutants of transport. There are a lot of measurements for both exhaust emissions and ambient concentration of certain pollutants. But for particulate matter, which can be considered today's most important pollutant, measurement methods, definitions and results are not compatible for exhaust measurements or ambient concentration.

Therefore, how can we do risk assessment for different measures considering transport? We give a short overview on our approach, on problems with measurements and present a possibility how to do risk assessment for particulate matter.

Background

Many studies have shown a big negative impact of Diesel-exhaust and particulate matter on human health. Therefore the retrofitting of (diesel) busses and the equipment of new cars with particle traps are intensively discussed.

Yet it is necessary to estimate the effectiveness of these measures for reducing the health risk. We estimated the cancer risk for different transport scenarios in the year 2020 in a recent investigation commissioned by the German Environmental Protection Agency. A key question of this task is: Do we need particle traps for health reasons? This puts the focus on diesel vehicles and on the trade-off between fewer greenhouse gas emissions but higher particulate emissions than gasoline power vehicles.

Methodology

There are different possibilities to assess exhaust emissions (Slide 3).

- Compare direct emissions
- Calculate relative risks
- Calculate air quality (impacts of transport)
- Estimate health impacts of transport

In a recent investigation[1] the relative health risk of gasoline and diesel powered cars as well as of diesel and LNG-busses were compared, for the different emission standards separately. Herefore the tailpipe emission factors, derived for urban conditions, were multiplied with the respective risk-factor per pollutant. The results show, that the health risk will decrease strongly in the future as the emission standards will be tightened strongly.

However there is still the open question, whether these reductions will be enough? To answer that question a method was developed to estimate the cancerogenic lifetime risk resulting from transport's exhaust pollutants (Slide 4):

[1] "Risikovergleich zwischen Dieselmotor- und Ottomotoremissionen...", in cooperation with FhG-ITA, Hannover et al., Erich Schmidt Verlag, Berlin 1999

Air pollutants are emitted by road vehicles and other sources. When we can estimate the share of transport to the ambient concentration of certain air pollutants and multiply with the respective risk factors we obtain the total risk.

The future air pollution from transport will certainly depend on its emissions. To estimate the future emissions we used the model "TREMOD" (Transport Emission Estimation Model). This model is validated for absolute fuel consumption in Germany and the relative time development of different pollutants (Slides 5-9). To calculate the future pollutant concentration due to transport we first estimate today's share of transport on the ambient concentration of a certain pollutant for a certain site, then calculate the future development of its transport emissions and finally apply the respective rate of change on the transport share of the ambient concentration. Assuming that in particular meteorological and chemical conditions stay the same, we obtain an estimate for the future pollutant concentration resulting from road vehicles (Slide 10-12).

Results

Because of stricter emission standards and better fuel qualities the emissions of benzene and particulates will decrease strongly. In consequence also near main roads the lifetime risk - considering carcinogenic substances - will be below 1:5.000 if Diesel-cars are equipped with particle traps. This will hold true even if the share of diesel cars increases strongly from today's 16 percent to as much as 50 percent. (The figures will change if HDV will not be equipped with particle traps, as assumed here.)

Considering PM_{10}, today we do not achieve the air quality goals (for example recommended by WHO and the new European Air Quality Directive) at many sites. Different studies show a big impact of transport on the PM_{10} concentration in ambient air. However for PM_{10} it is not possible to estimate the future air quality with our approach: First the interactions between exhaust aerosol, testing parameters and ambient aerosol need to be better understood as well as the influence of secondary particles and the high background. This will need to better harmonise measurement methods and definitions for both emission and air quality measurements (Slides 14-16).

We can conclude that emission models are validated for fuel consumption and many pollutants. Therefore they allow to calculate future emissions of transport. This can be used for risk assessment of exhaust pollutants. For many pollutants the health risk will decrease strongly in future. However for particulate emissions from transport there is a big uncertainty: There are no time resolved measurements and consequently the emission factors cannot reflect dynamics. The dilution and sampling methods differs between measuring tailpipe emissions and ambient concentrations. A good approach could be to use elemental carbon as a tracer for particulate emissions from transport. Otherwise the method presented here allows to estimate the future life time cancerogenic risk. For PM_{10}-measurements and modelling there are still many open questions (Slide 17).

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4. ETH Conference on Nanoparticle-Measurement
Zürich, 7. August 2000

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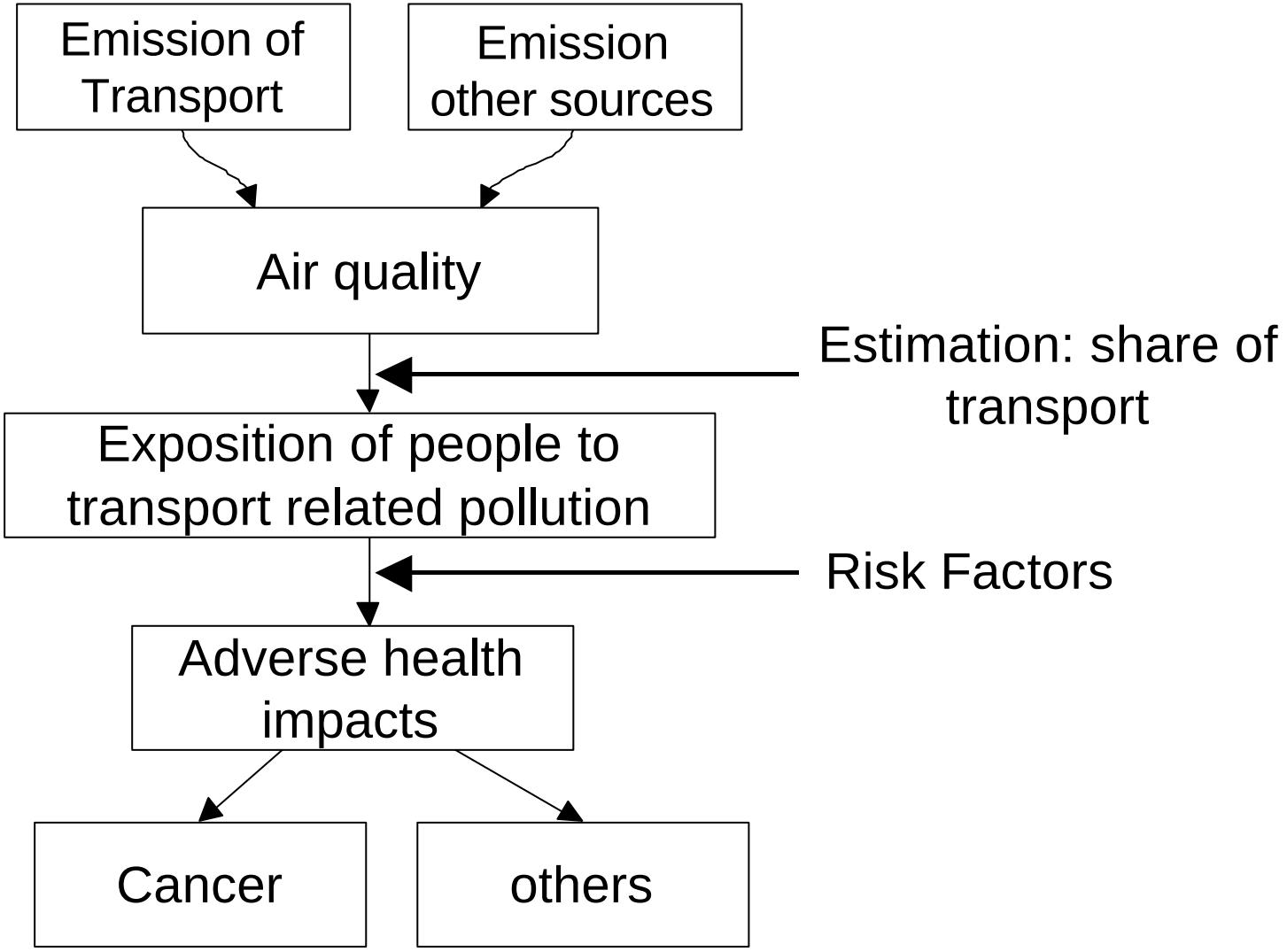
Structure

- Possibilities to evaluate exhaust emissions
- TREMOD – the German transport emission model
- Method for the estimation of future air quality
- Problems of modelling particle emissions from transport
- Results of risk analysis of road transport emissions
- Conclusions

Possibilities to evaluate exhaust emissions

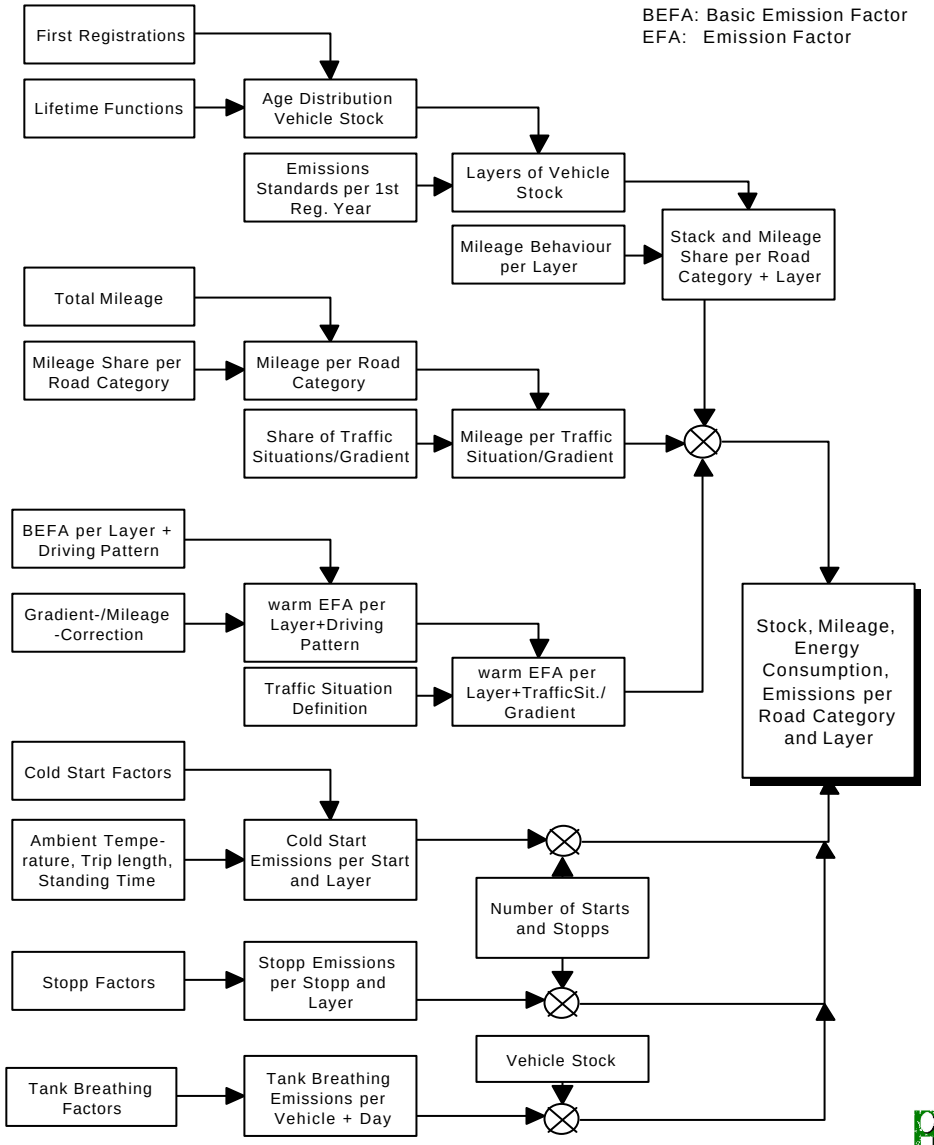
- Compare direct emissions
  - Mass of pollutants
  - Number/particle size distribution
- Calculate relative risks
  - (Mass of pollutants) x (Risk factor)
- Calculate air quality (impacts of transport)
  - Will we reach today´s and future air quality goals?
- Estimate health impacts of transport
  - What is today´s and what will be the future health risk caused by transport?
  - Is the reduction we gained by new technique (e.g. particle traps) enough?

Simplified scheme of risk assessment of transport



Emission Calculation in TREMOD

- **modelling all relevant factors**:
  - driving behaviour,
  - mileage,
  - load factor,
  - differentiated emission factors,..
- **Estimation of.**
  - fuel consumption and.
  - exhaust and evaporative emissions (CO2, CO, NOx, NMHC, CH4, benzene, SO2, **particulates**, N2O, NH3).
  - for all motorized passenger and goods vehicles.
  - for Germany year by year from 1980 to 2020.
  - for various scenarios.



Validation of model results: Energy Consumption

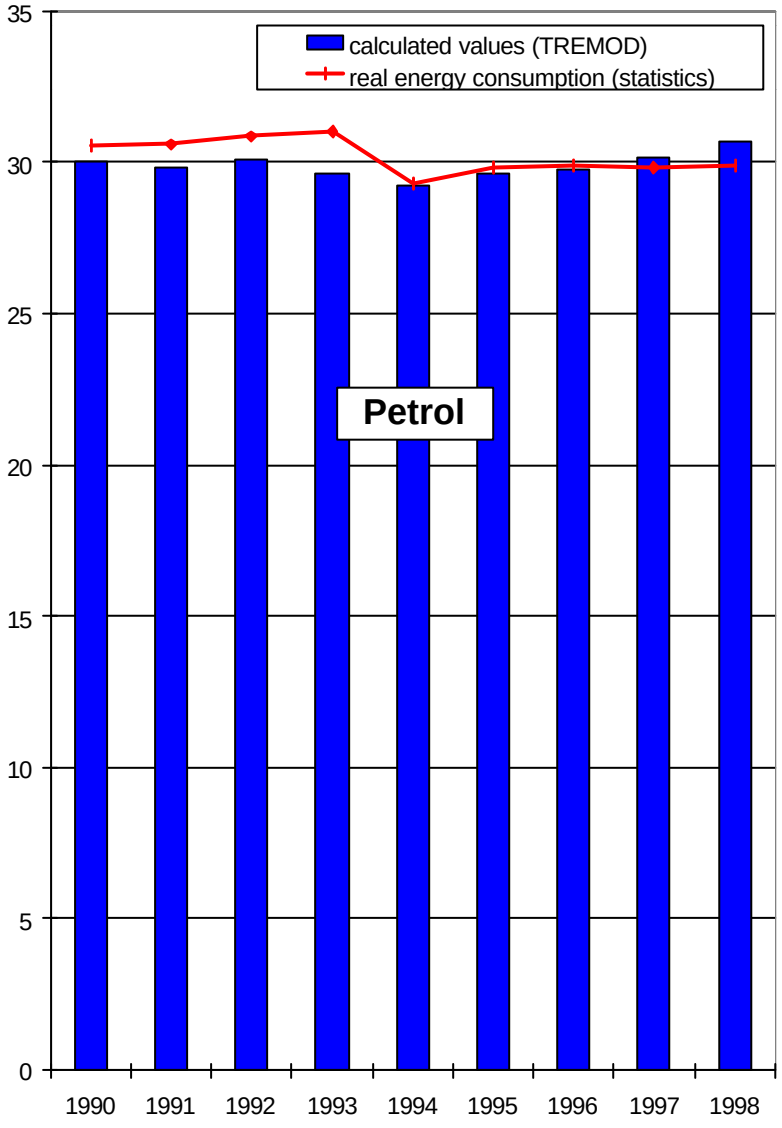
- Comparison of modelled fuel consumption with trade figures
- Assumption: The total fuel selling corresponds with the actual consumption

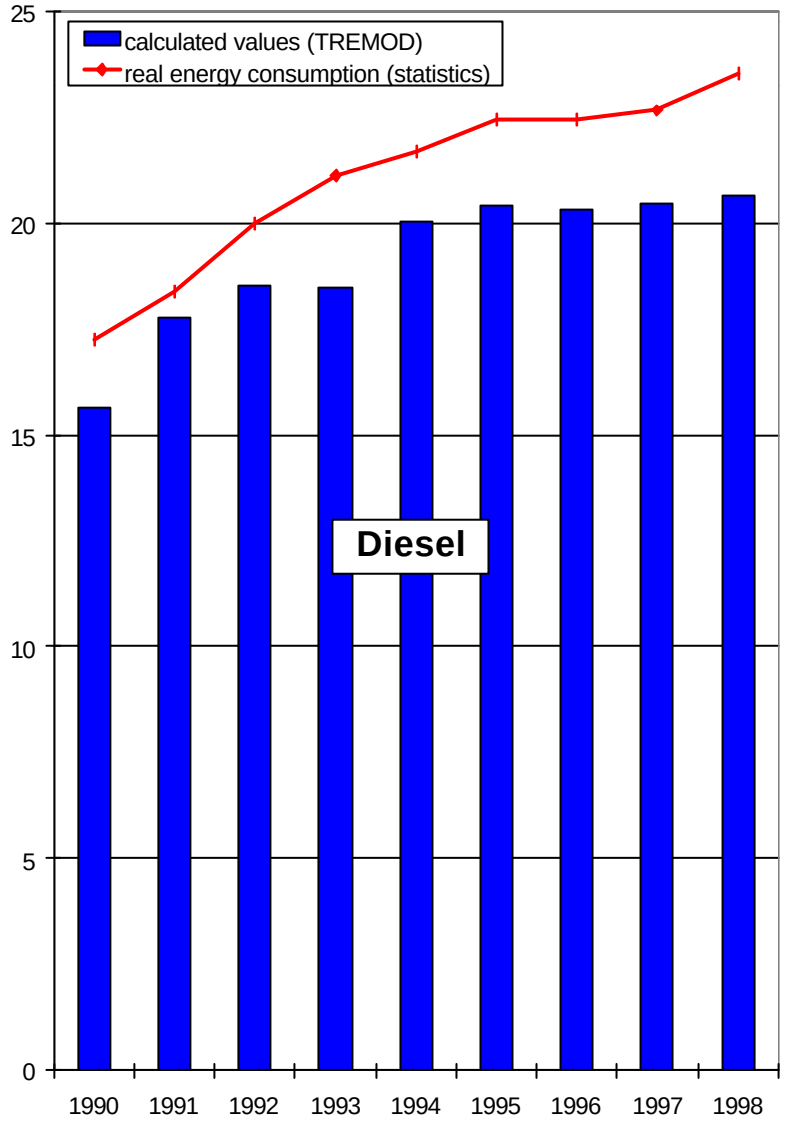
Results

➔ Very good correspondence for gasoline

➔ Good correspondence for Diesel fuel (problematic distinction between road transport and other consumers [agriculture, military, stationary consumers]. Refilling of Heavy Duty vehicles abroad)

Comparison of TREMOD results with the energy statistic





Validation of model results: Emissions of pollutants

- No possibility to measure the total emissions from transport.
- High uncertainty of calculated air quality from emission inventories and dispersion models; approximation only for local situations.

➔ Comparison of the time development of model results with air quality measurement at different (traffic dominated) sites.

  ➔ Selection of appropriate situations (only at few sites air quality measurements and traffic counting exist for a longer period).

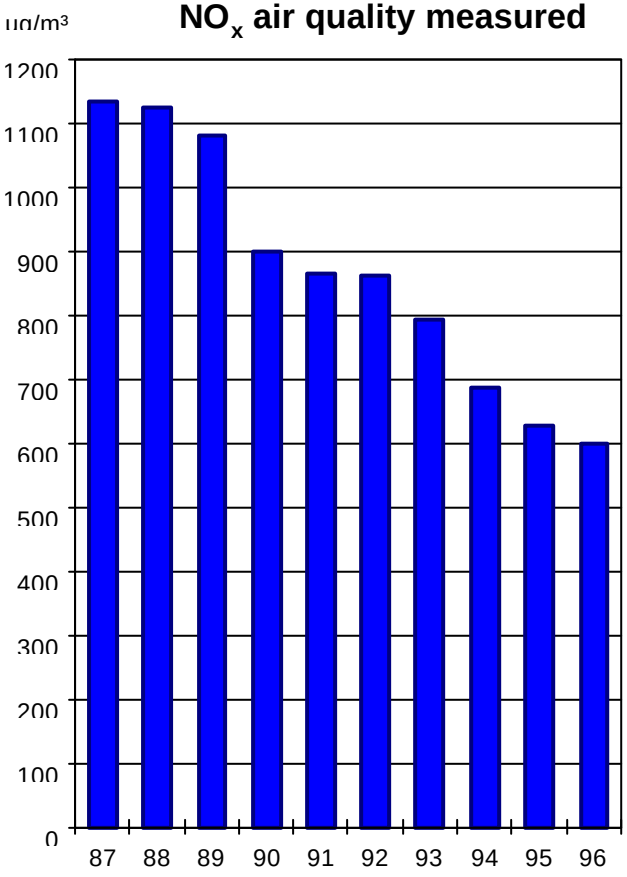
  ➔ Model estimations adapted to these individual situations.

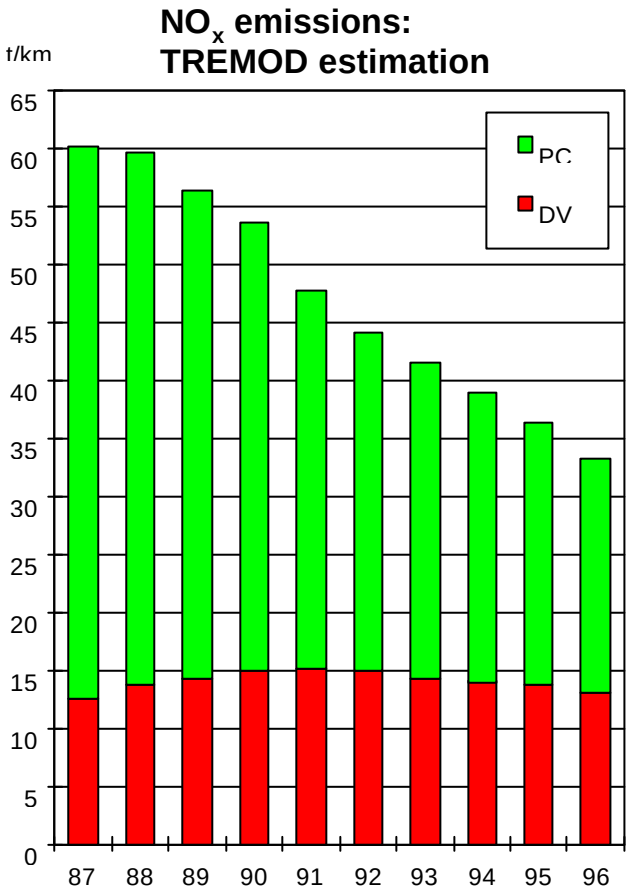
Results

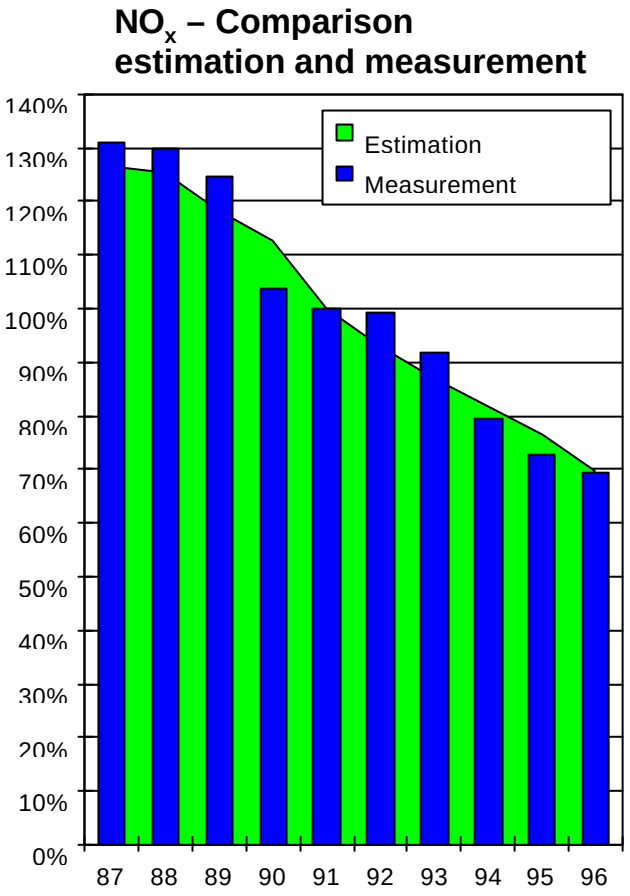
➔ High correspondence for the time development of the estimated emissions and measured air quality (Nitrogen Oxide and Carbon monoxide).

➔ Therefore the model reflects the changes during the past situation and is – in principle – well suited to predict future developments.

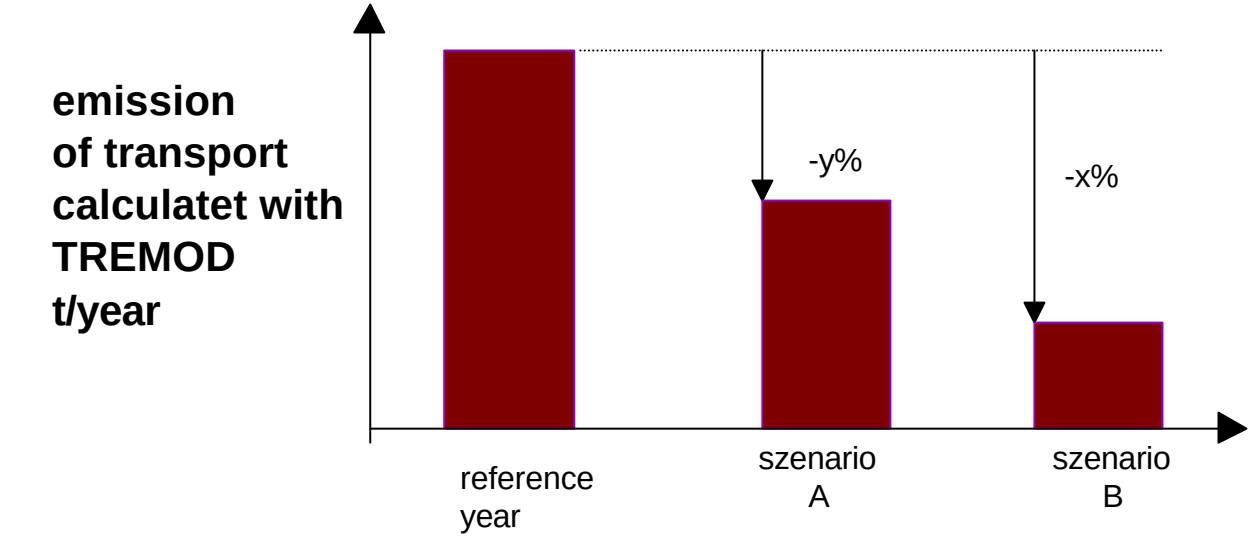
Comparison of TREMOD results with air quality measurement. Autobahn near Cologne



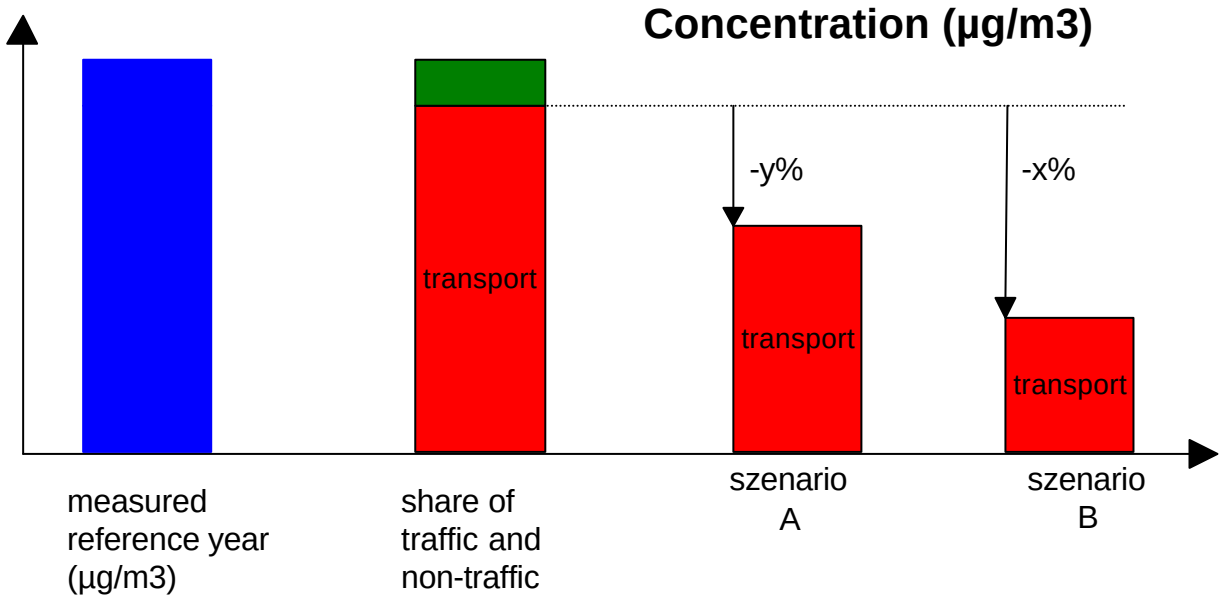




Simplified scheme to project the future air quality



Apply the reduction rates to calculate future air quality



Requirements for the use of this scheme to estimate air quality and health impacts of transport

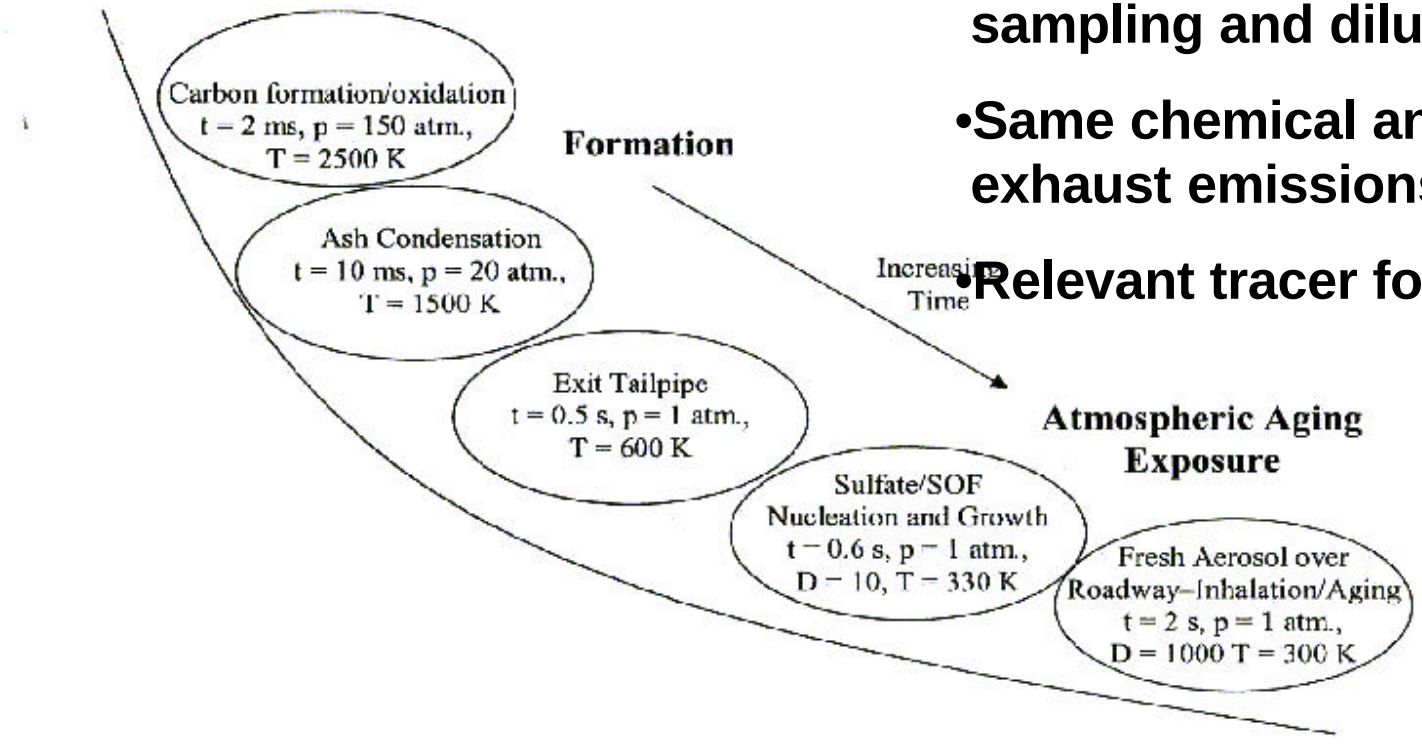
- One property of substance should be characteristic
  - Mass/spectrum
- Same measurement methods – no influence of measure methods
  - Emission measurements (dilution tunnel)
  - Air quality
- Little influence of other sources
- Assumed constant influence of chemical sequestering
- Meteorology (strength and direction of wind, frequency of inversions, etc.) is assumed as constant
- Selecting the most important and for transport characteristic (carcinogenic) substances
  - Elemental carbon
  - Benzene
  - BaP

Problems considering today´s emission factors of particulate matter and EC

- Particulate matter (standard)
  - Dilution/Sampling methods have big influence on particulate matter mass
  - Particulate matter is a very inhomogenious substance
  - At low particulate levels: more precise measurements are needed
  - Weak correlation between measured mass to ambient mass
  - No time resolved measurements
  - Correlation between emissions and air quality not possible
- Elemental carbon
  - Only few measurements
  - Representative estimation of share on PM
  - Ambient air also contains EC from tyres

Why did we select Elemental Carbon as tracer for doing the risk analysis of particulate matter?

Particle Formation History: From the Start of Combustion to the Nose

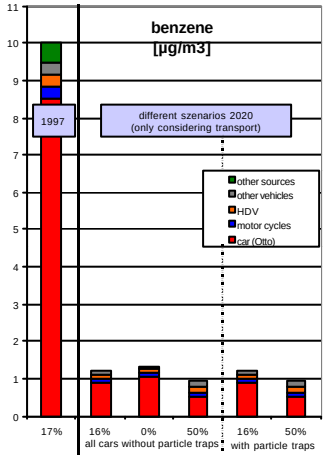


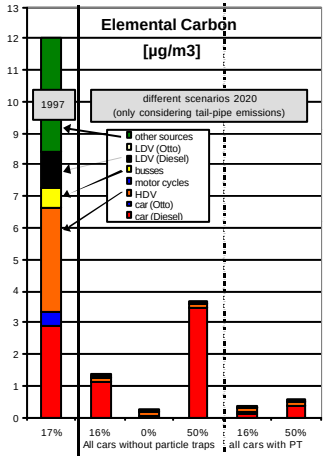
Selected as relevant tracer:
Elemental Carbon

- **High share of transport on pollution**
- **Measured mass not influenced by sampling and dilution conditions**
- **Same chemical analysis for exhaust emissions and air quality**
- **Relevant tracer for estimation of cancer risk**

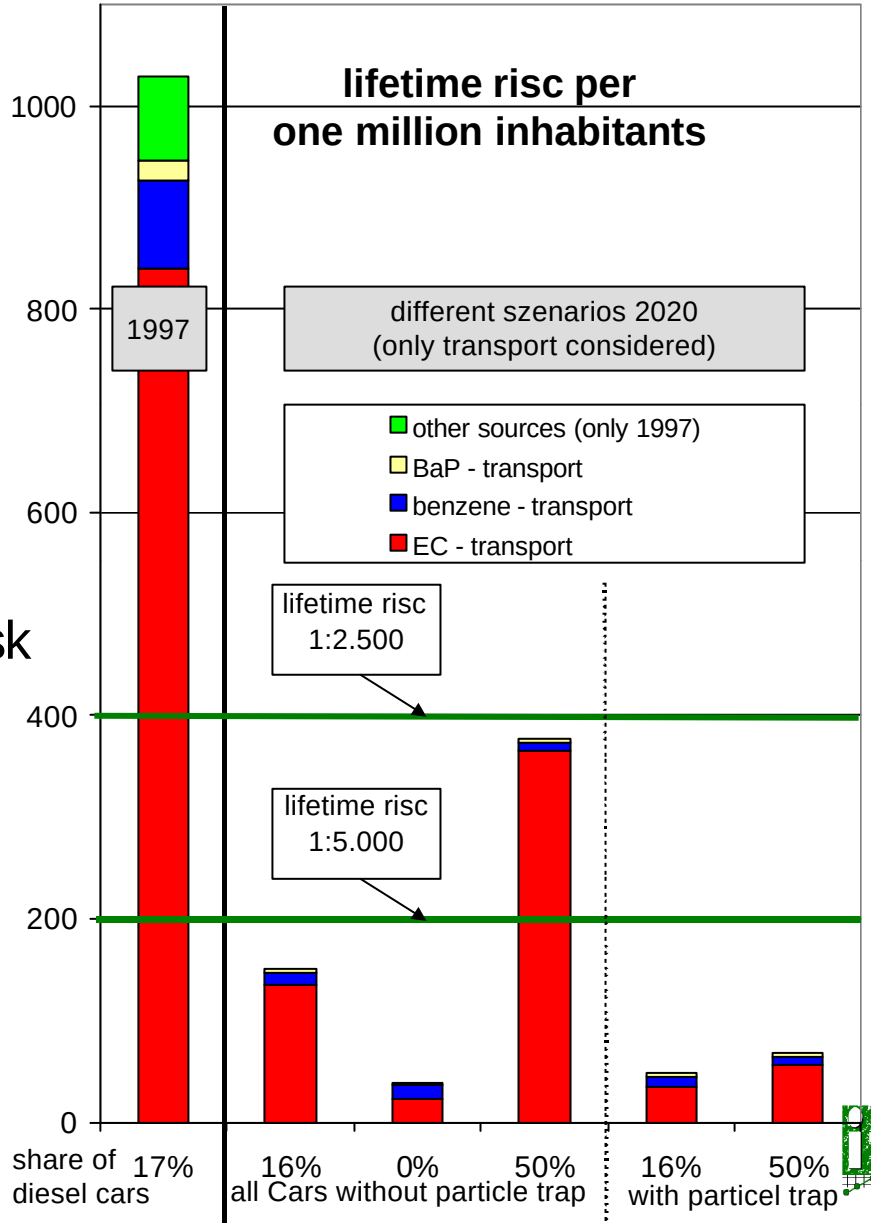
Estimation of today and future health risk near busy roads

Air quality modelling:
- different scenarios,
- different pollutants





Lifetime risk =
Σ Concentration * Unit Risk



Do we reach the environmental targets considering carcinogenic substances?

- **Because of the future emission standards and fuel qualities there is a big decrease of benzene and particulate emissions**
- **Also near the main roads the lifetime risk will be under 1:5.000 if Diesel-Cars are equipped with particle traps**
- **The figures will change if HDV are not equipped with particle traps**

Situation considering particulate matter (PM10)

- **Today we do not achieve the air quality goals (for example WHO, new European Air quality directives) considering PM10 in many sites**
- **Different studies show a big impact of transport on PM10 concentration in ambient air**
- **For PM10 it is not possible to make a statement with our approach for future air quality**
  - **high influence of secondary particles**
  - **high background pollution**
  - **The relationships between exhaust aerosol, testing parameters and ambient aerosol is still not well understood**

Conclusions

- **Emission models are validated for many pollutants and energy consumption**
  - Principally they allow to calculate future emissions of transport
  - They can be used for risk assessment
- **There is a big uncertainty in estimation particulate emission from transport**
  - No time resolved measurements – no dynamics in emission factors
  - Dilution and sampling methods differs between measuring tailpipe emissions and air quality
- **Approach to do risk assessment**
  - Considering EC as tracer for particulates from transport
  - Estimation of future life time risk (cancer) possible
  - Open questions considering PM10