

12th ETH-Conference on Combustion Generated Nanoparticles
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Paper/Poster-Abstract Form

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Title: Effects on emissions, air quality and health of congestion charging and the low emission zone in Stockholm

NOTE: this presentation is for the FOCUS EVENT on LEZ Wednesday 25th, 14.00-17.30

Abstract: (min. 300 - max 500 words)

The abstracts for papers and posters should contain unpublished information on the research subject, the investigation methods and results obtained so far. Graphs and references are very welcome. During your presentation at the conference you may expand on this with additional data and results. General information on products which are already commercially available are not the focus of the presentations but are very welcome at the exhibition.

2 page Abstract:

Effects on emissions, air quality and health of congestion charging and the low emission zone in Stockholm

In Swedish studies traffic exhaust effects on acute effects on asthmatics has been seen (Forsberg et al., 1998). Also long-term exposure with NO₂ as marker has associations been shown with the prevalence of respiratory problem (Forsberg et al., 1997), lung cancer incidence (Nyberg et al., 2000), deaths in myocardial infarction (Rosenlund et al., 2006) and incidence of adult asthma (Modig et al., 2006). In Stockholm both the EU-directive for PM₁₀ (Norman & Johansson, 2006) and the national limit value for NO₂ (98-percentile of daily mean values) are exceeded along several roads in the city. On June 2, 2003, Stockholm City Council proposed testing congestion charging of traffic — the Stockholm Trial. On June 16, 2004 the Swedish Parliament, the Riksdag, adopted the Congestion Charge Law (SFS 2004:629). The Stockholm Trial consisted of three parts: extended public transport, congestion tax and more park-and-ride sites in the city and the county. Today congestion charging is a permanent system in Stockholm. In addition, Stockholm has a special low emission zone that applies to heavy duty trucks and buses. The effect of the Stockholm Trial on emissions and levels of air pollutants is presented as well as the estimated consequences for health. The impact of the low emission zone will also be discussed.

The effects of the Stockholm Trial on air quality and health have been assessed by using estimates of emissions from road traffic. The total road use, i.e. the number of vehicle kilometres driven within a specific area was estimated partly with a statistical method and partly by using model calculations. Levels and exposure was obtained using an air quality dispersion model. Population data with a high spatial resolution, 100 x 100 m grids for the whole region together with model calculated changes in air pollutants concentrations. The health impact assessment (HIA) presented is restricted to long-term effects on mortality, and uses the same approach as used by for example WHO and Swedish national assessments (Forsberg et al, 2005).

The average levels of nitrogen oxides (NO_x) are estimated to fall by at most 5-10 µg/m³ and the levels of particles, PM₁₀ by at most 2-3 µg/m³. The levels of air pollutants increase in an area around the tollfree bypasses. The EU limit values for both PM₁₀ and NO₂ would still be exceeded along the most densely trafficked streets. But as a whole, considerably more people in Stockholm experienced reductions in air pollutants and better air quality compared with those who experienced increased levels.

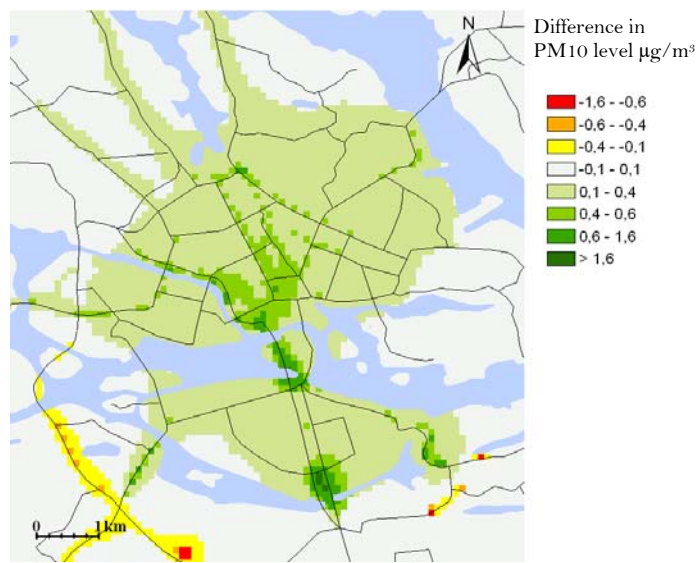


Figure 1. Changes in levels of particles (PM₁₀, mean annual levels) with the Stockholm Trial compared with levels without the congestion charge for 2006.

Studies from Holland, New Zealand, France and Norway (Hoek et al., 2002; Scoggins et al., 2004; Filleul et al., 2005; Nafstad et al., 2004) have shown an increase in mortality of 12%, 13% and 14% per 10 µg/m³ increase in nitrogen dioxide, NO₂, respectively. The Norwegian study, was considered the most relevant for the consequence analysis of the effects of the Stockholm Trial. In that study they arrived at an increased premature mortality of 8% per 10 µg/m³ increased level of nitrogen oxides, NO_x. Then the reduction in level in Greater Stockholm area (1.44 million inhabitants), is expected to result in approx. 20 to 25 fewer premature deaths per year.

Conclusions

The "Stockholm Trial" involved a road pricing system to improve the air quality and reduce traffic congestion. With charges for vehicles during weekdays (only daytime and most expensive during rush-hours) it resulted in a 15% reduction in total traffic volume in Stockholm's inner city. The emissions of particles and nitrogen oxide from road traffic fell by 8%-12% in Stockholm's inner city (inside the charged cordon). With a permanent congestion tax, both the average particle levels for the population of Stockholm and the nitrogen oxide levels would be some percent lower as annual average. The limit values for both PM₁₀ and NO₂ would still be exceeded along the most densely trafficked streets. Based on the calculated reduced population exposure the lowered number of premature deaths was estimated using an exposure-response factor for NO_x. Despite relatively small changes in total concentrations, it is estimated that between 25 and 30 premature deaths would be avoided as a result of a reduction in long-term exposure to particles. NO_x is merely regarded as an

indicator of traffic exposure. This is only the tip of the ice-berg since improvements in both airway and cardiovascular disease is expected to be reduced as well. This study demonstrates the importance of not only assessing the effects on air quality, but also to make quantitative estimates of health impacts, in order to justify actions to reduce air pollution.

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- Gehring U, Heinrich J, Kramer U, Grote V, Hochadel M, Sugiri D, et al. *Epidemiology.* 2006;17(5):545-51.
- Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA. *Lancet.* 2002;360(9341): 1203-9.
- Scoggins A, Kjellstrom T, Fisher G, Connor J, Gimson N. *Sci Total Environ.* 2004;321(1-3):71-85.
- Forsberg B, Stjernberg N, Linne R, Segerstedt B, Wall S. *Eur Respir J.* 1998;12(4):900-5.
- Nyberg F, Gustavsson P, Järup L, Bellander T, Berglind N, Jakobsson R, et al. *Epidemiology.* 2000;11(5):487-95.
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- Modig L, Järvholm B, Rönnmark E, Nyström L, Lundbäck B, Andersson C, et al. *Eur Respir J.* 2006;28 (1):75-81.
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Short CV:

Christer Johansson is an associate professor (Docent) at the department of Applied Environmental Science, Stockholm University, where he is a supervisor of PhD students and the principal investigator of several research projects in the field of urban air quality.. He defended his Ph.D at the department of Meteorology, Stockholm University, 1988. He is also employed at Environment and Health Administration, City of Stockholm as an Environmental Officer.

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Effects on air quality and health of congestion charging and the low emission zone in Stockholm

Christer Johansson

Environmental officer at EHA, Stockholm



also

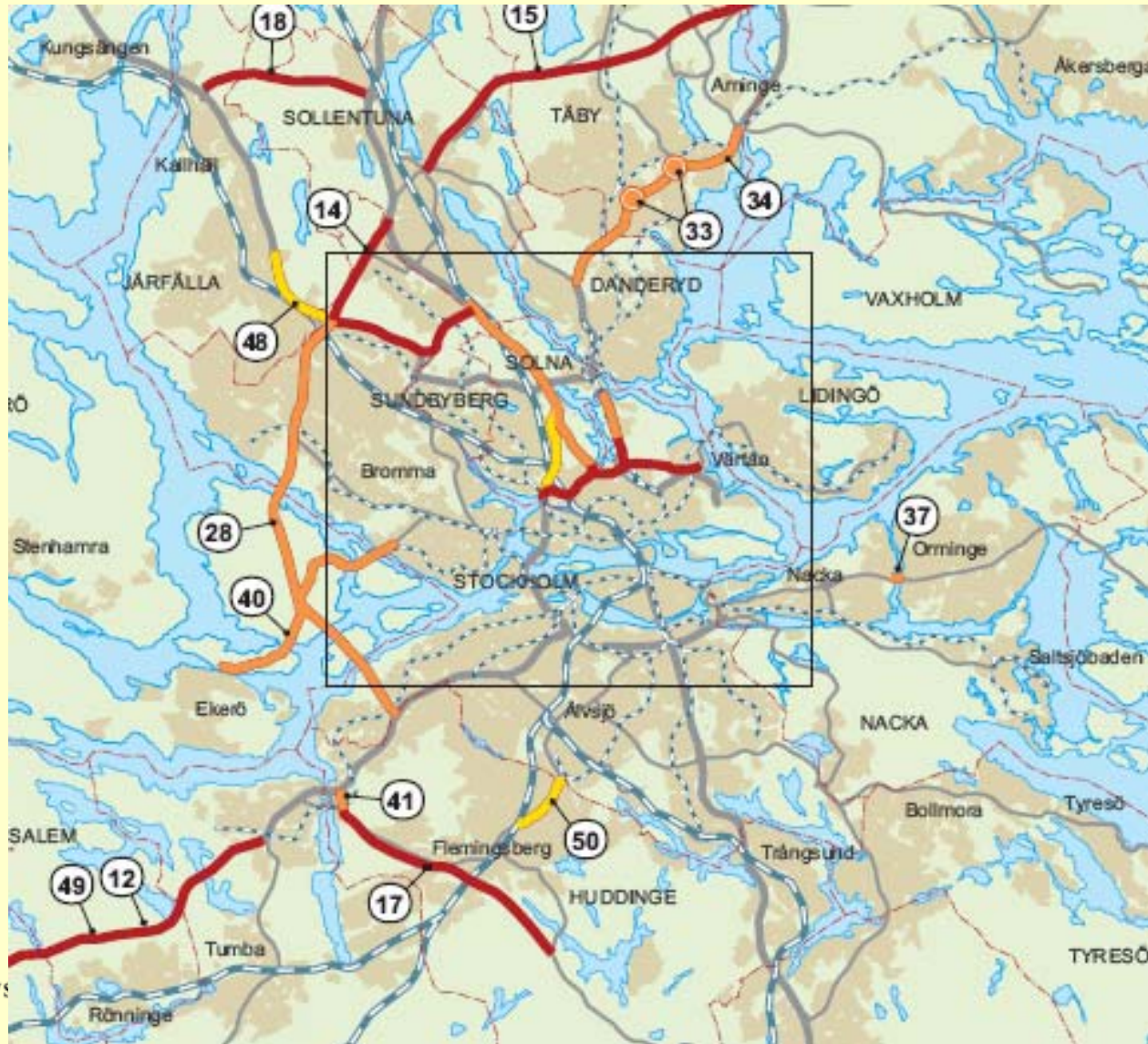
Associate professor at the Department of Applied Environmental Science, Stockholm University



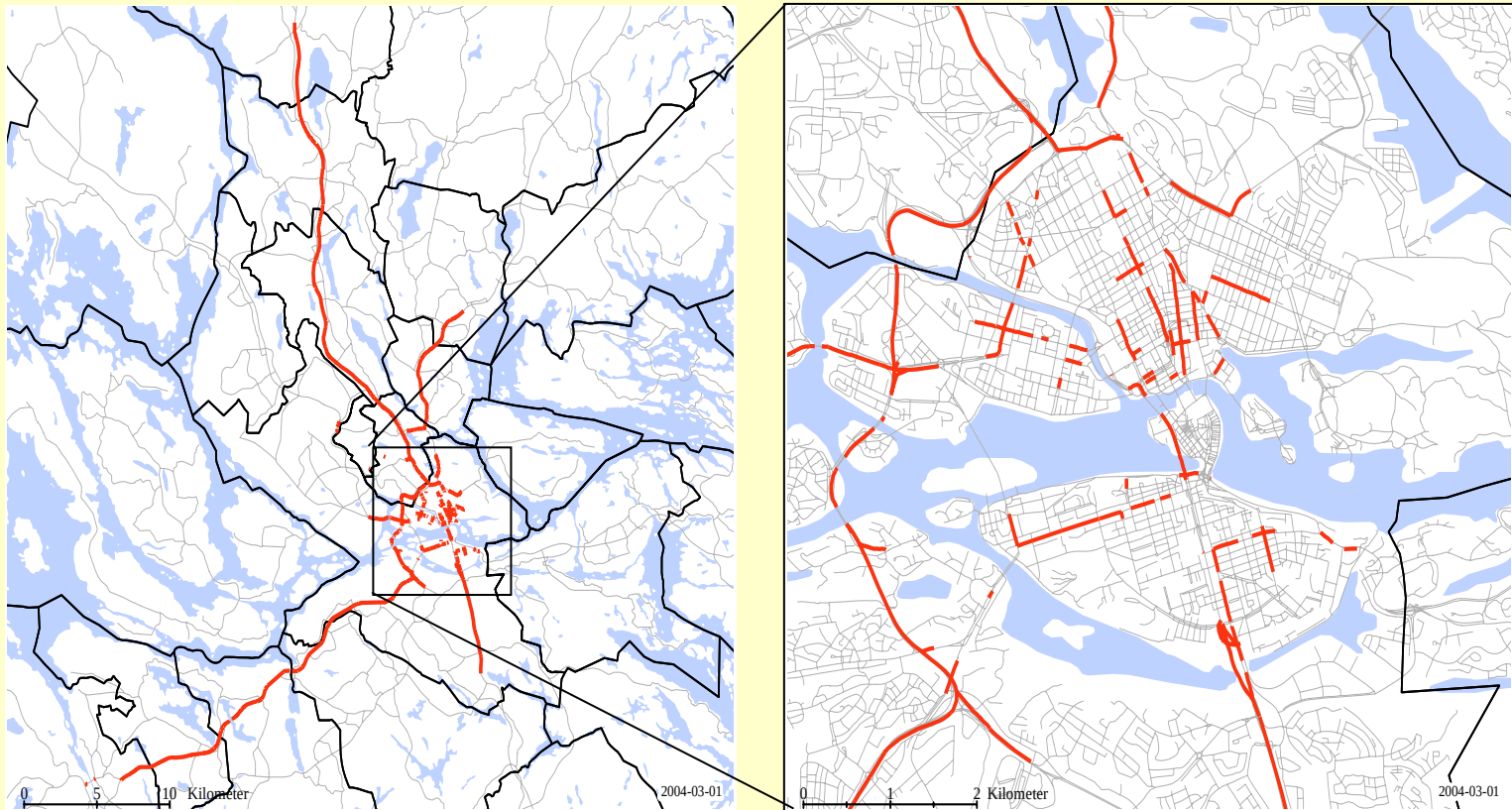
Outline

- Background
 - Congestion a big problem
 - Air quality in Stockholm illegal
- Congestion charge
 - Stockholm trial
- Low emission zone
 - HDV emissions of NOx, PM-exhaust
- Health efficiency of other measures

Bottlenecks in road network, lack of N-S connections



Exceedances of EU limit values for PM10 and NO₂



Main objectives...

- **Reduce traffic volumes**
10-15 % during rush hours
- **Reduce emissions of**
carbon dioxide, nitrogen oxides and particles
- The residents of Stockholm should perceive
an **improvement in the urban environment**

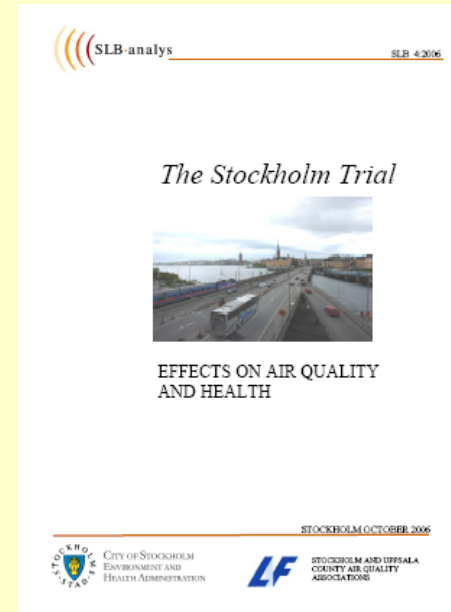


Extensive evaluation

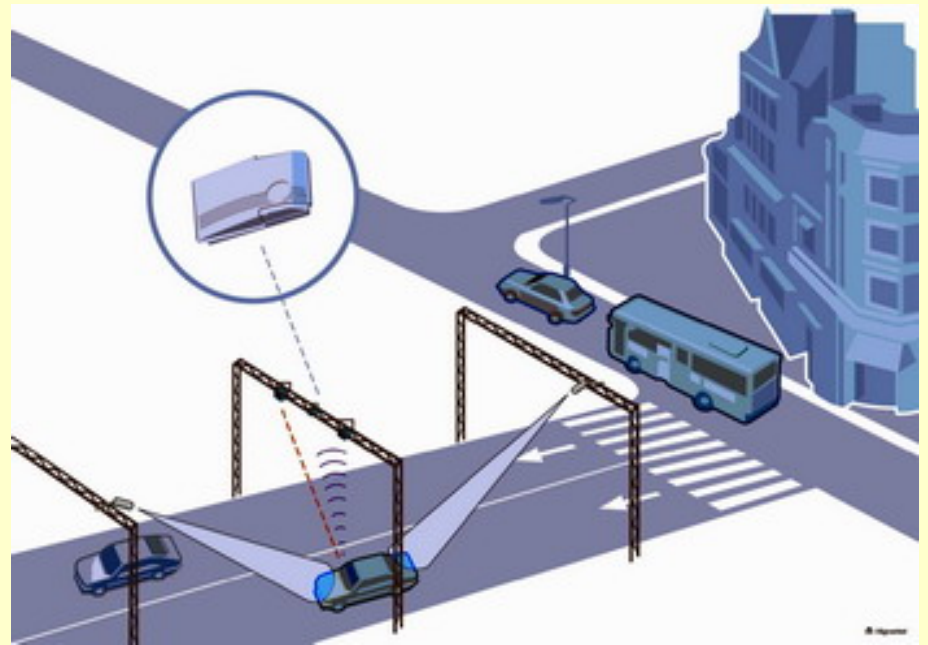
- **25 Reports:**

- Commuting, travel times, public transport, bicycle rides
- Traffic volumes, traffic jam, traffic security
- City environment, noise, air quality, emissions, health
- Taxi, delivery services, road maintenance, children's activities
- Economical analyses, cost- benefit, regional economy

<http://www.stockholmsforsoket.se>



18 automatic toll stations



- Jan 3 - Jul 31, 2006
- More park- and ride sites
- Extended public transports

Time of day (weekdays)	Tax	(In other currencies)
---------------------------	-----	-----------------------

00:00 – 06:29	0 SEK	
06:30 – 06:59	10 SEK	1.09 EUR, 1.48 USD
07:00 – 07:29	15 SEK	1.63 EUR, 2.23 USD
07:30 – 08:29	20 SEK	2.17 EUR, 2.97 USD
08:30 – 08:59	15 SEK	
09:00 – 15:29	10 SEK	
15:30 – 15:59	15 SEK	
16:00 – 17:29	20 SEK	
17:30 – 17:59	15 SEK	
18:00 – 18:29	10 SEK	
18:30 – 23:59	0 SEK	



Maximum amount per
vehicle and day – 60 SEK
- 6.50 EUR

Methodology

Calculations

Traffic change & emissions

Air quality

Exposure & health effects

Measurements

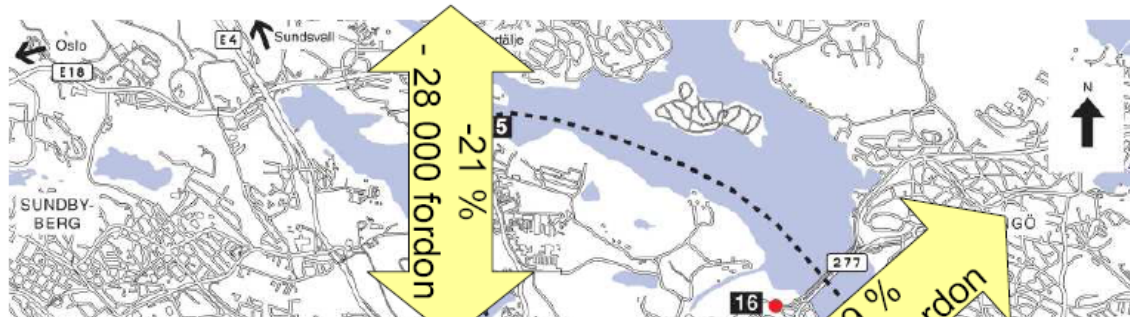
Traffic

Air quality

Meteorology



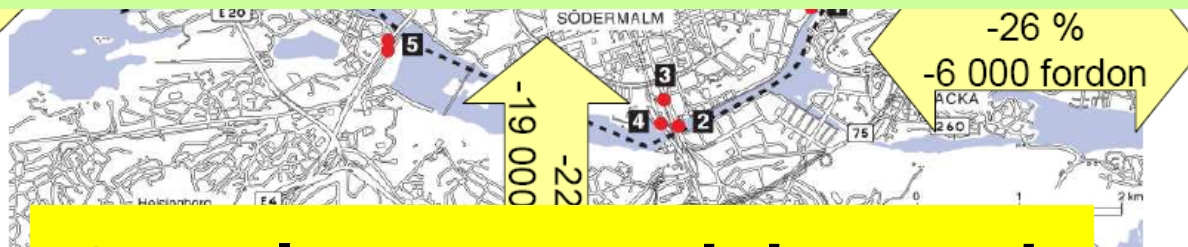
Substantial decline in traffic



-22 % = -100 000 passages

Inner city:

15 % less total vehicle kms



Goal was achieved!

Increased traffic on
highway connecting north – south
& tunnel connecting east – west

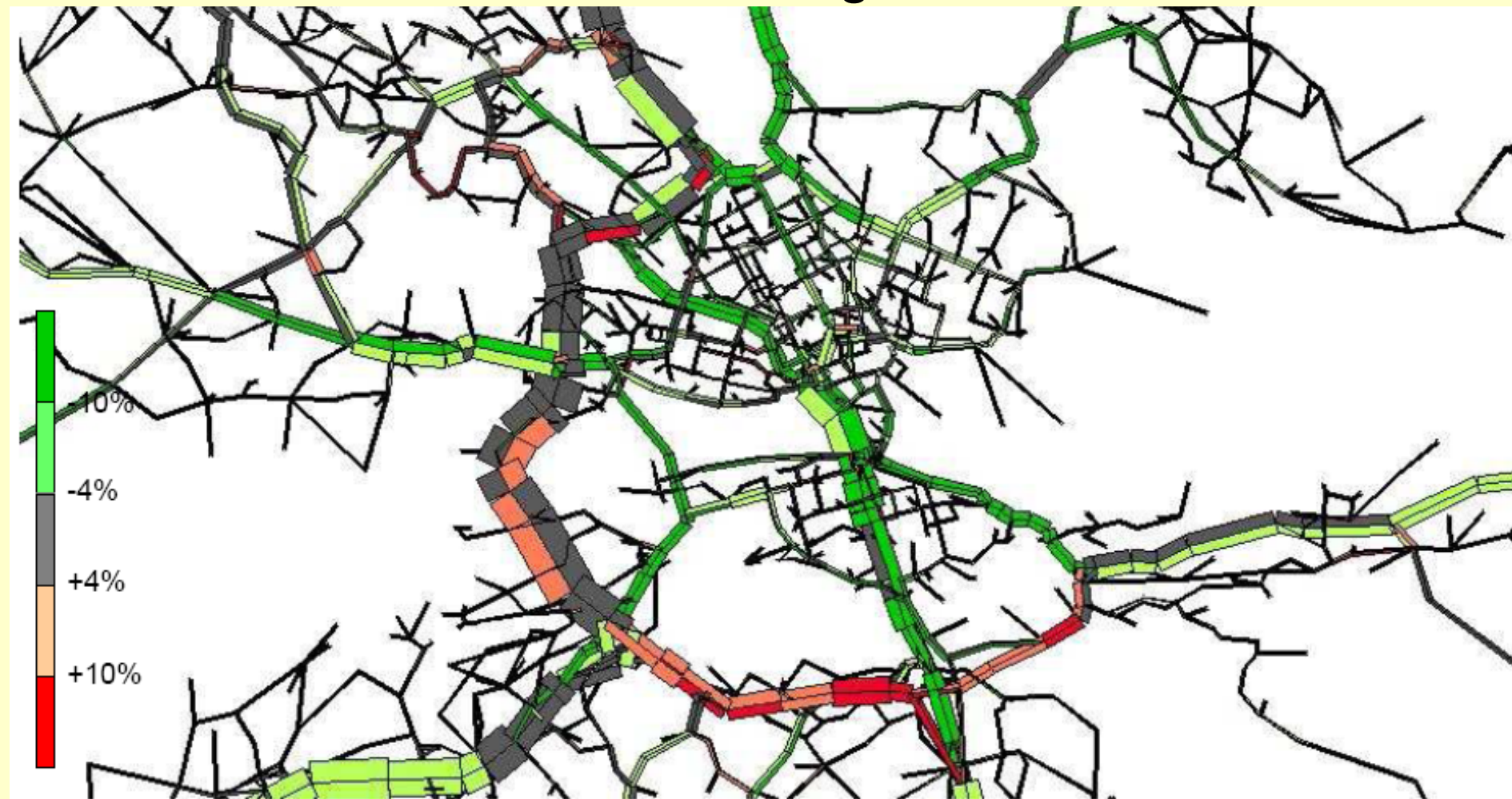


Figure 2. Change in traffic volumes (weekdays, 24-hour period), April 2005 compared to April 2006.

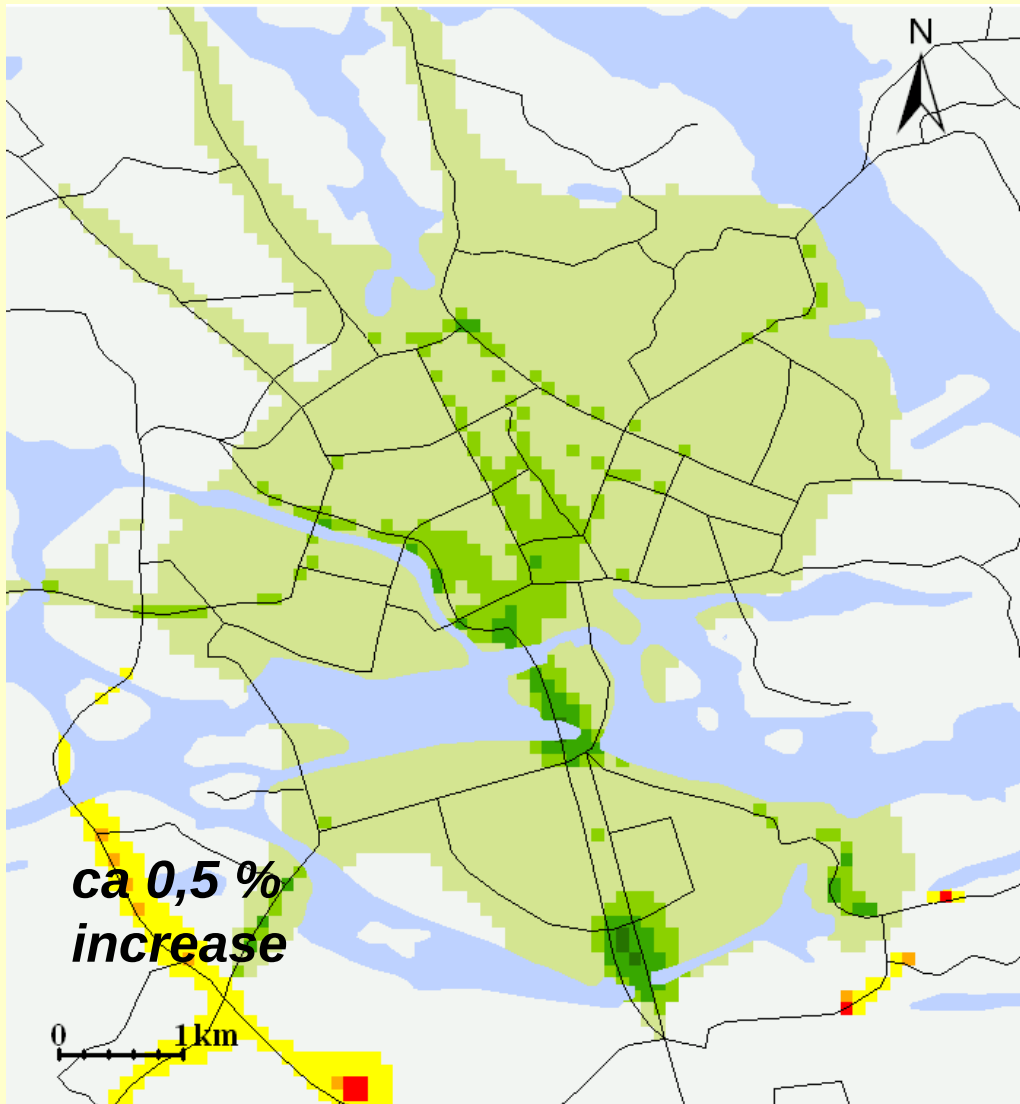
Results – Emissions

Goal was achieved!

Zone	Skillnad i %				
Tidsperiod	Pb	Llb	Tlb	Buss	Totalt
06-09	-19,1	-17,4	-4,5	34,8	-17,4
09-15	-18,9	-12,3	-8,8	17,3	-16,9
15-18	-18,8	-19,3	-6,9	21,3	-17,8
18-06	-10,9	-13,5	-10,7	7,1	-10,7
00-24	-16,5	-15,0	-7,8	18,4	-15,5

<i>Decrease in city centre 2006:</i>	<i>tonnes/ year</i>	<i>%</i>
Nitrogen oxides, NO _x	45	-8,5
Carbon monoxide, CO	670	-14
Particles, PM10 total	21	-13
” wear particles	19	-13
” exhaust particles	1,8	-12
Hydrocarbons, VOC	110	-14
” benzene	3,4	-14
Carbon dioxide, CO ₂	38 000	-13

PM10 changes



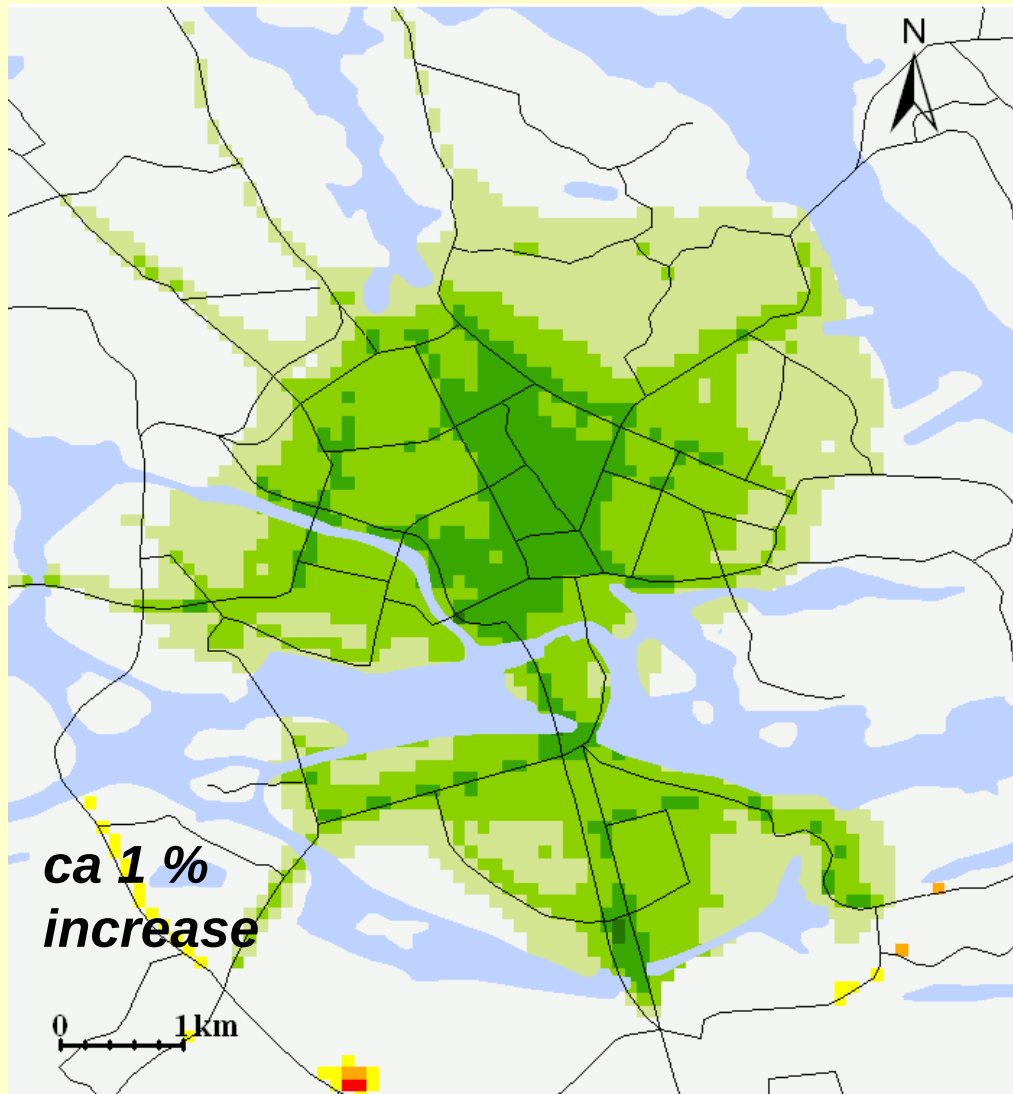
Skillnad i partikelhalt
(PM10), $\mu\text{g}/\text{m}^3$



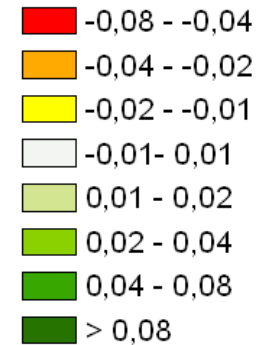
***Roof level, city centre
ca 2 % decrease***

***Street level, city centre
4-8 % decrease***

PM exhaust particle changes



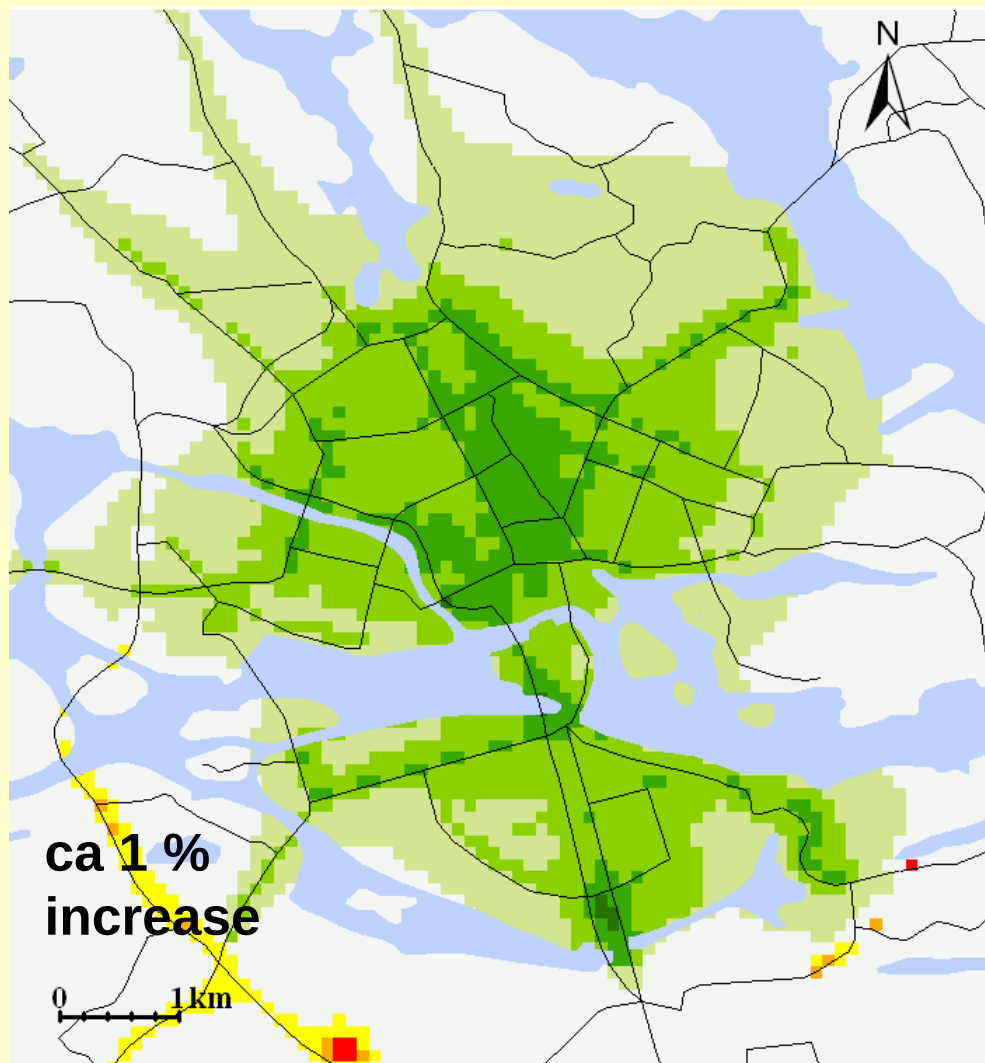
Skillnad i partikelhalt
(avgaspartiklar), $\mu\text{g}/\text{m}^3$



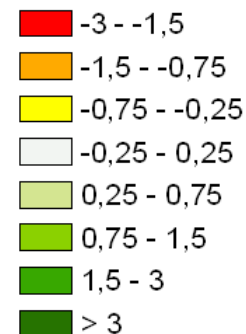
***Roof level, city centre
5-6 % decrease***

***Street level, city centre
5-10 % decrease***

NOx changes



Skillnad i NO_x-halt,
µg/m³



***Roof level, city centre
ca 6 % decrease***

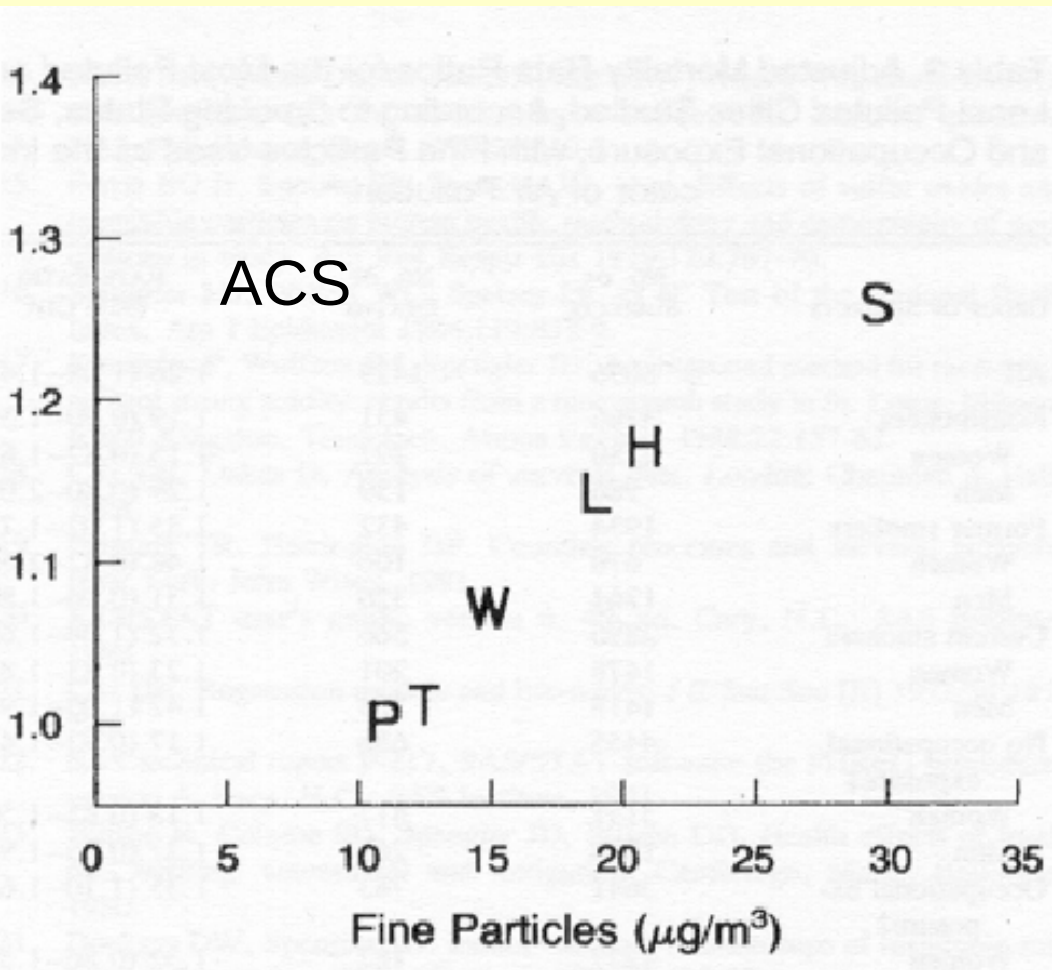
***Street level, city centre
5-10 % decrease***

Small changes in population mean concentrations

Greater Stockholm area (1.44 million people; 35x35 km)

	No trial	Trial	Difference
NOx	4.42	4.19	0.23 (-5.3%)
PM10	1.71	1.65	0.064 (-3.8%)
PM exhaust	0.102	0.0960	0.0062 (-6.1%)

Exposure response factor, PM2.5



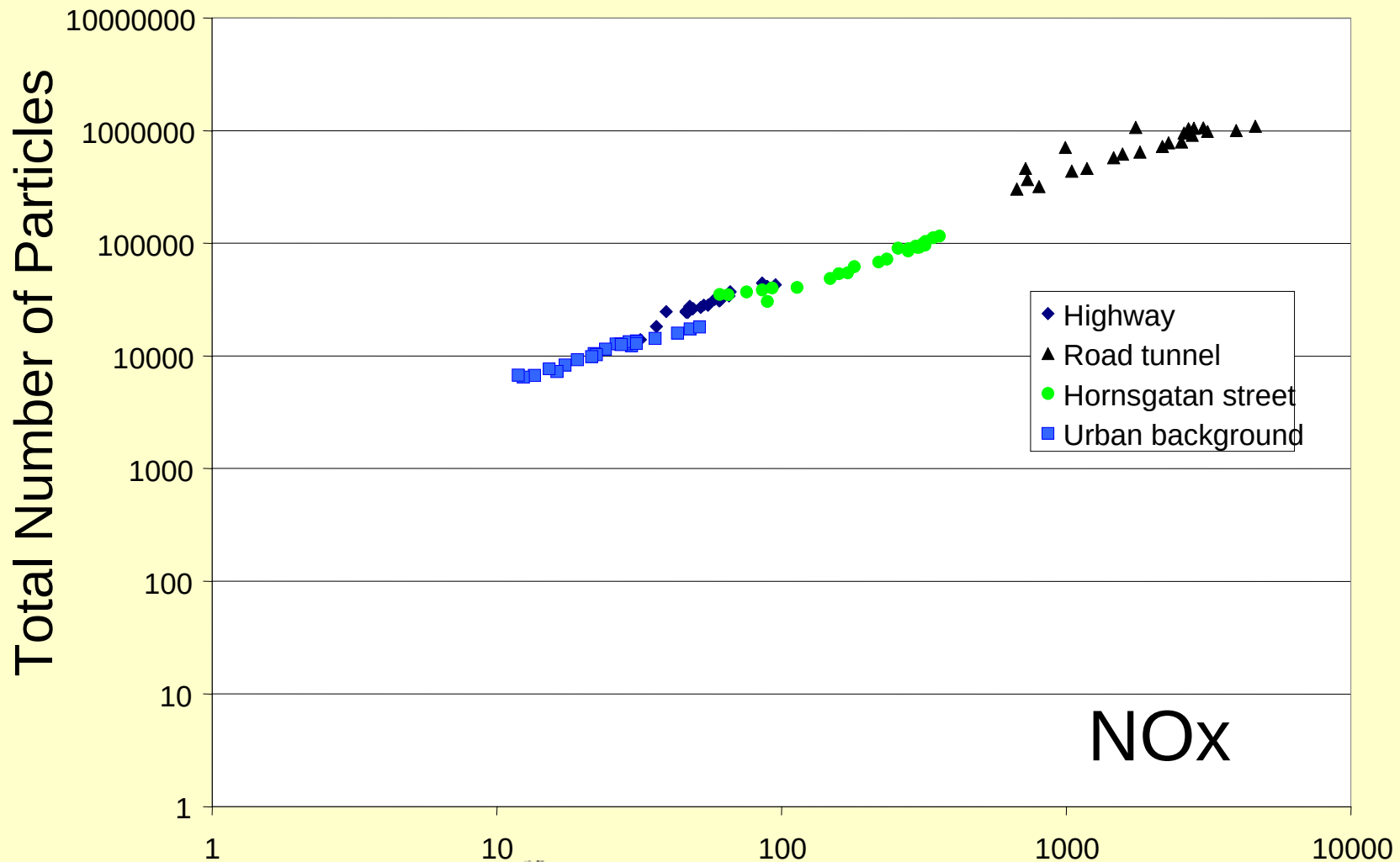
**6% increased mortality
per $10 \mu\text{g}/\text{m}^3$ PM2.5**

Exposure response factors:

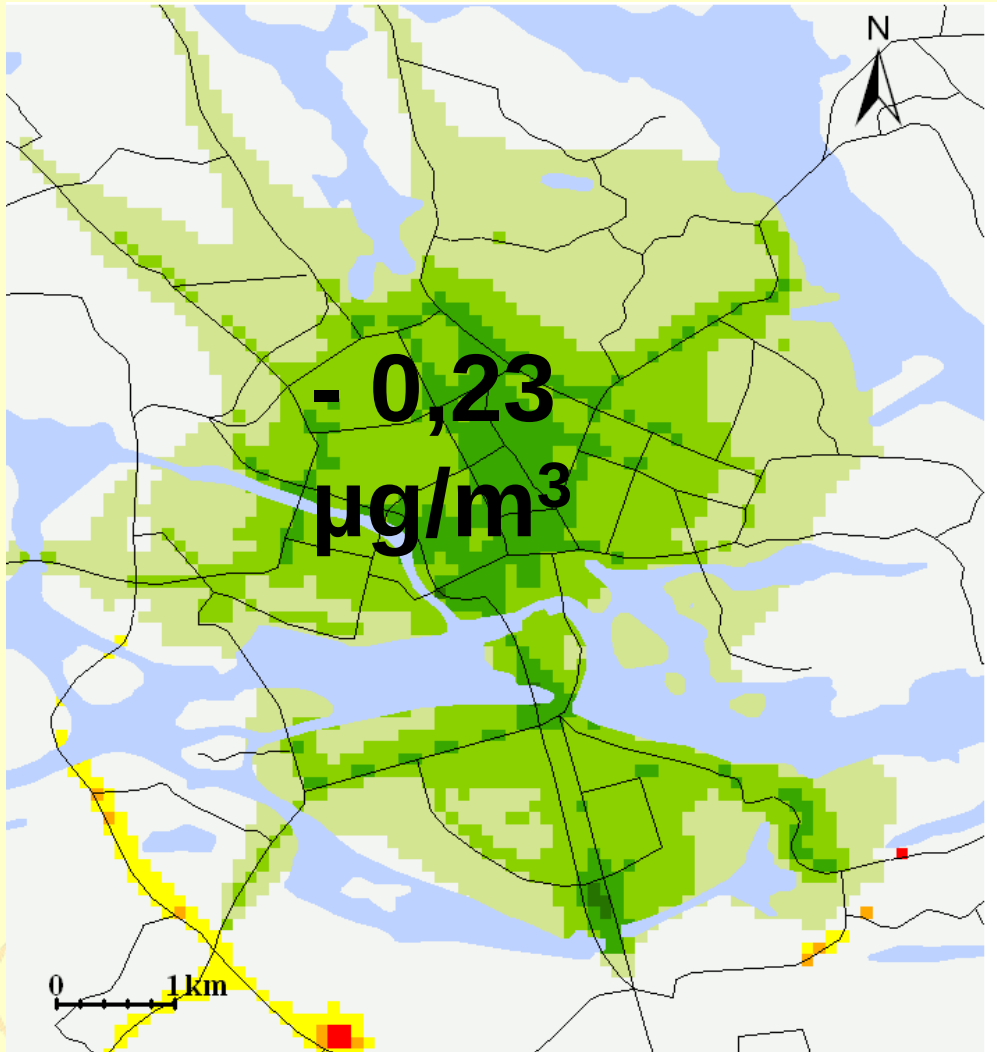
NO₂ & NO_x

- For long term mortality for different populations and subgroups:
 - per 10 µg/m³ NO₂
 - Holland: 12% (Hoek et al., 2002)
 - Germany: 17% (Gehring et al, 2006)
 - New Zealand: 13% (Scoggins et al. 2004)
 - France: 14% (Filleul et al., 2005)
 - per 10 µg/m³ NO_x
 - Norway: 8 ± 3 % (Nafstad et al., 2004)
- increased cardio-vascular mortality

NOx and PM-exhaust highly correlated



Population weighted reduced exposure of NOx...



Assuming:

Permanent system

Sustained effect of Trial
on traffic

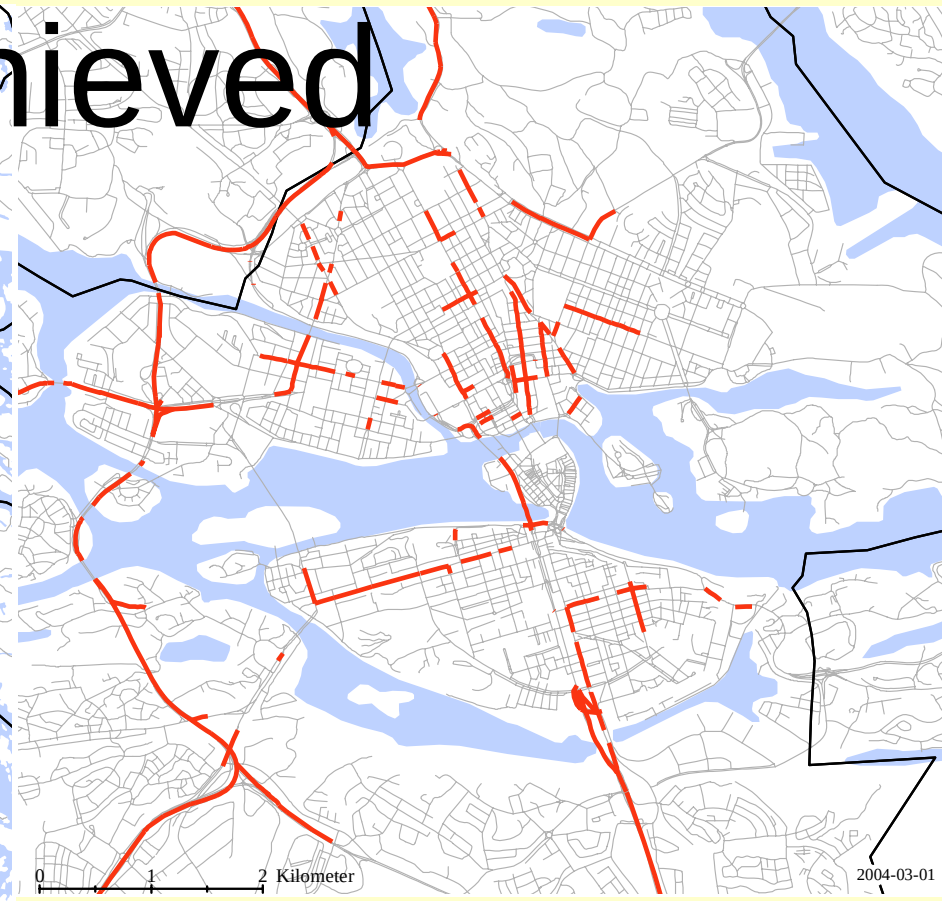
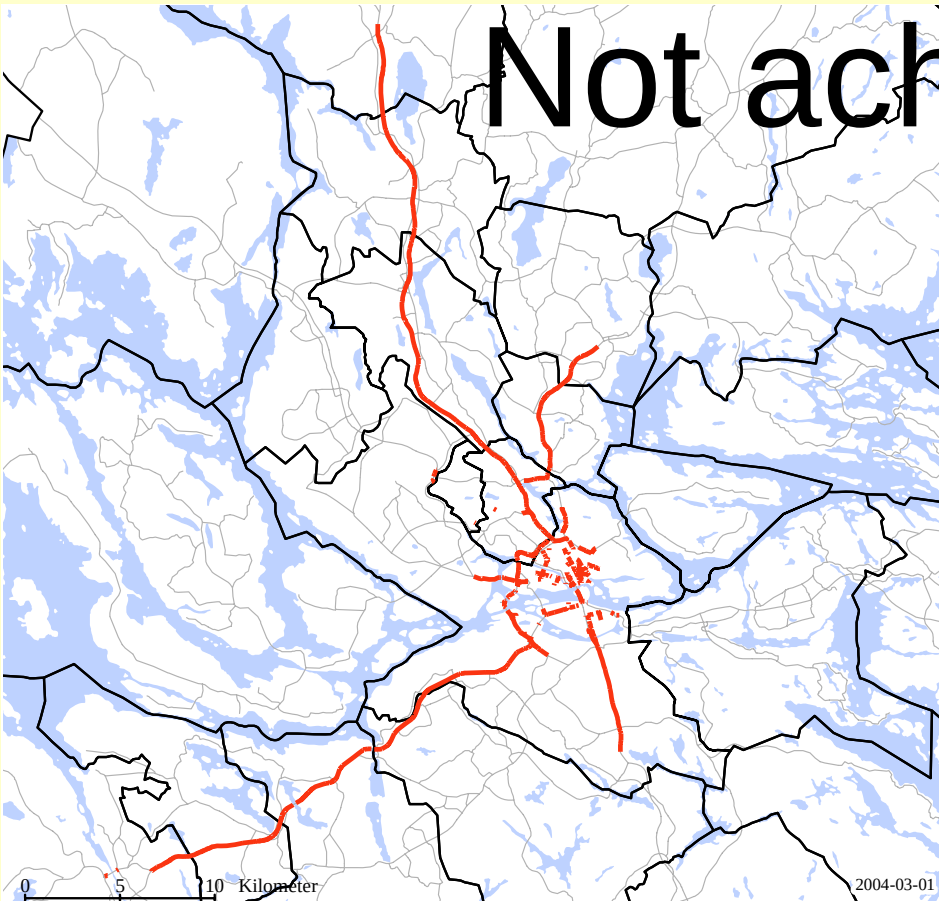
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Long term mortality effects if Stockholm trials are permanent

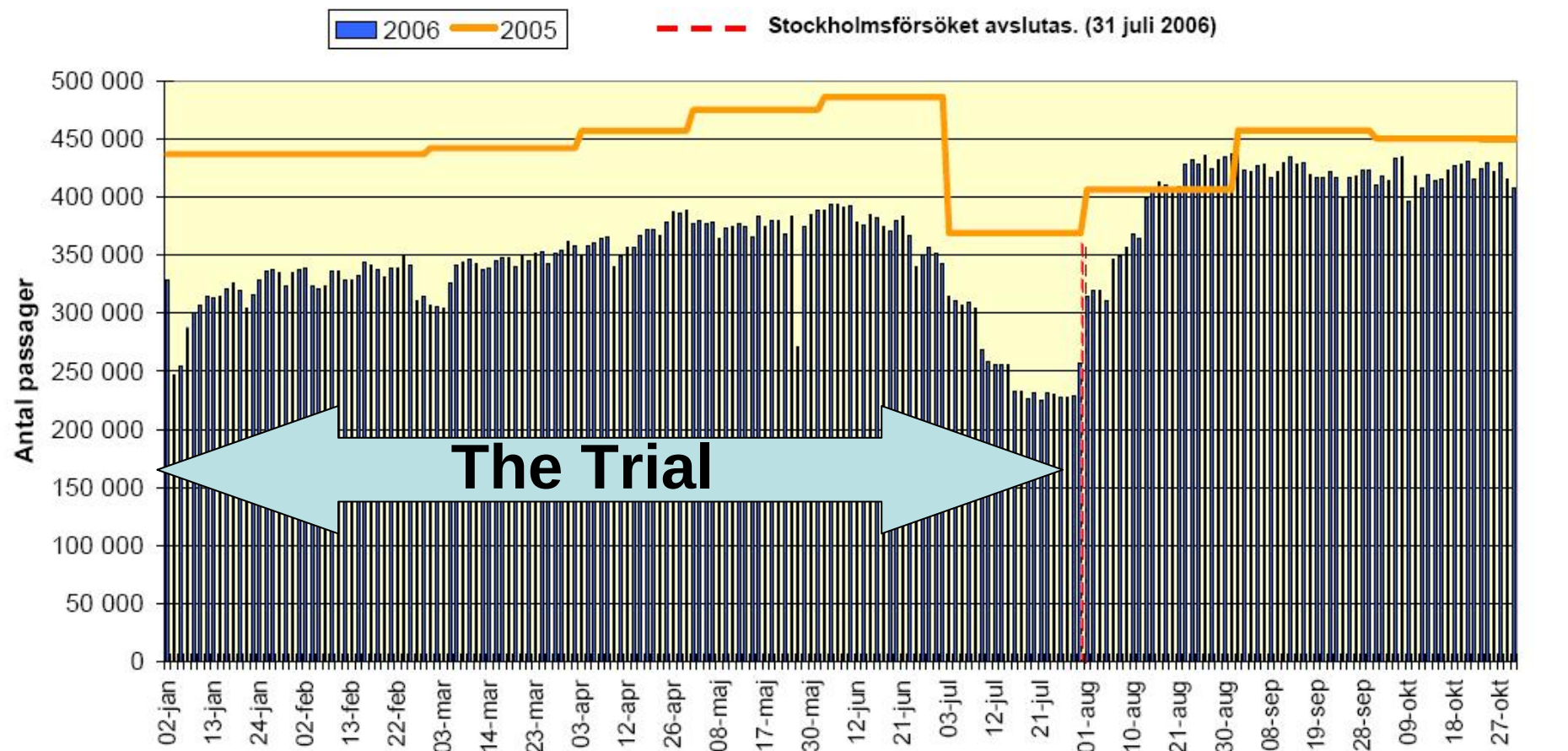
- Reduced exposure based on population weighted decrease of NO_x concentrations
 - Decrease of 0,23 ug/m³
 - 1.44 million residents
 - Baseline mortality: 1000/100 000
 - **Expected to give 26 (20 – 36) fewer premature deaths per year**

Limit values for PM10 and NO2?

Not achieved



After the Trial...



Permanent system from Aug 1st

- Similar system as the congestion tax trial (area, control points, charging, extended public transports...)
- The revenue will go entirely to new road constructions around Stockholm.
- The congestion tax is deductible for both private individuals and businesses.



Cost benefit surplus

- Cost: SEK 2.6 billion
- Annual surplus: SEK 760 million
 - Shorter travel times (SEK 600 mill)
 - Increased road safety (SEK 125 mill)
 - Health & Environment (SEK 90 mill)
 - Revenues (SEK 550 mill)
- 4 years payback time

The goals were achieved

- "10 - 15 % mindre trafik till/från innerstaden"
- – Blev 20-25%
- • "Ökad framkomlighet"
- – Kötiderna ner 30-50% i och kring innerstaden
- – Essingeleden ung. som förut
- • "Minskade utsläpp"
- – 14% mindre i innerstaden; 2,5% i länet
- • "Invånarna ska uppleva att stadsmiljön förbättras"
- – Oklart – svårt att definiera och mäta

Conclusions

- Large traffic reduction
- Lower emissions
- Small effect on concentrations
- Expect big effect on health
- Cost-effective measure

The Environmental Zone in Stockholm



Rule:

HDV not older than 6 years

Year of registration	As per general rule	Euro 2	Euro 3	Euro 4 + adapted vehicles	Euro 5 + EEV + adapted vehicles
1998	2004	2006			
1999	2005	2007			
2000	2006	2008			
2001	2007	2009	2009		
2002	2008		2010		
2003	2009		2011		
2004	2010		2012		
2005	2011		2013	2016	
2006	2012		2014	2016	2020
2007	2013			2016	2020
2008	2014			2016	2020
2009	2015			2016	2020
2010	2016				2020





Colette van Luik

abc

00:04



Stockholms
Slöds
Parkering AB
08/772 96 00

Turisterna får se Stockholm till fots.

01:07



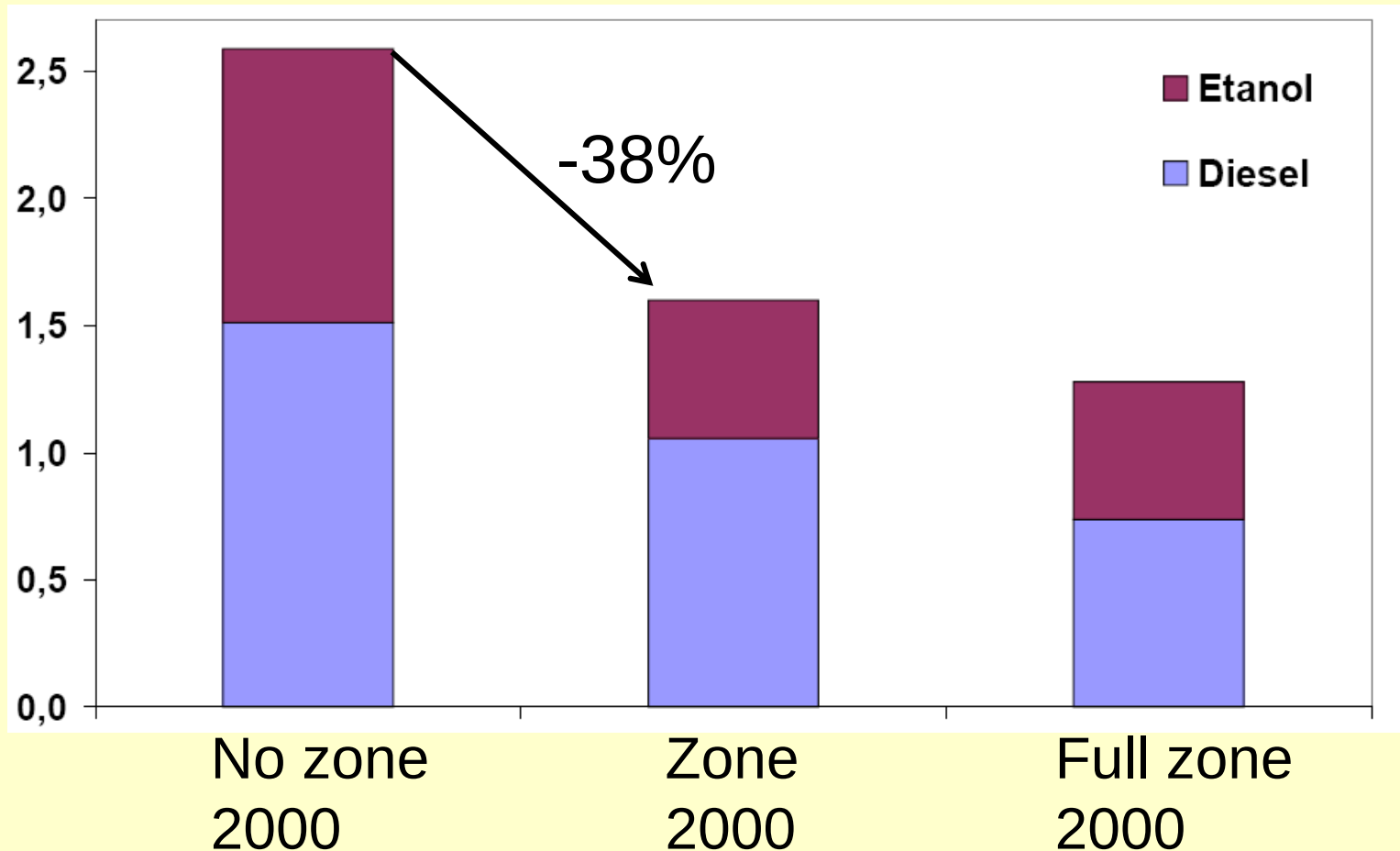


fotograf **Peter Ström**
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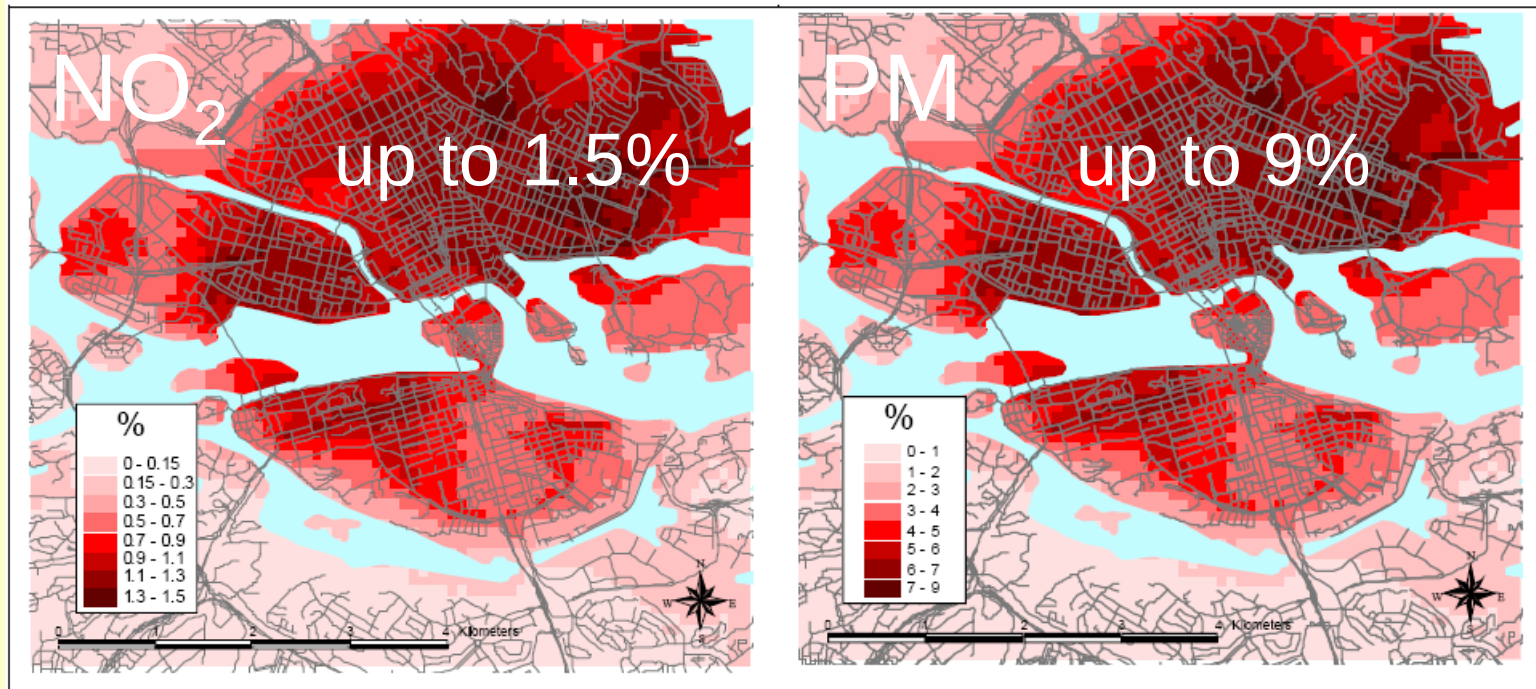


Harald Scheilinger
busschaufför

Effect on PM exhaust emissions



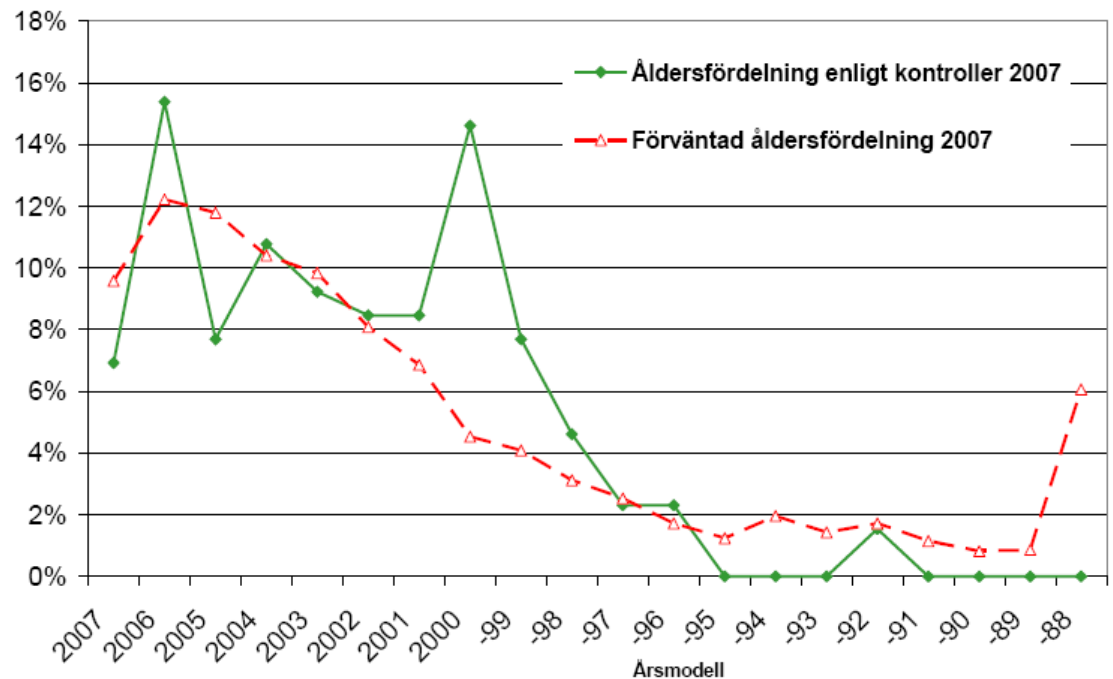
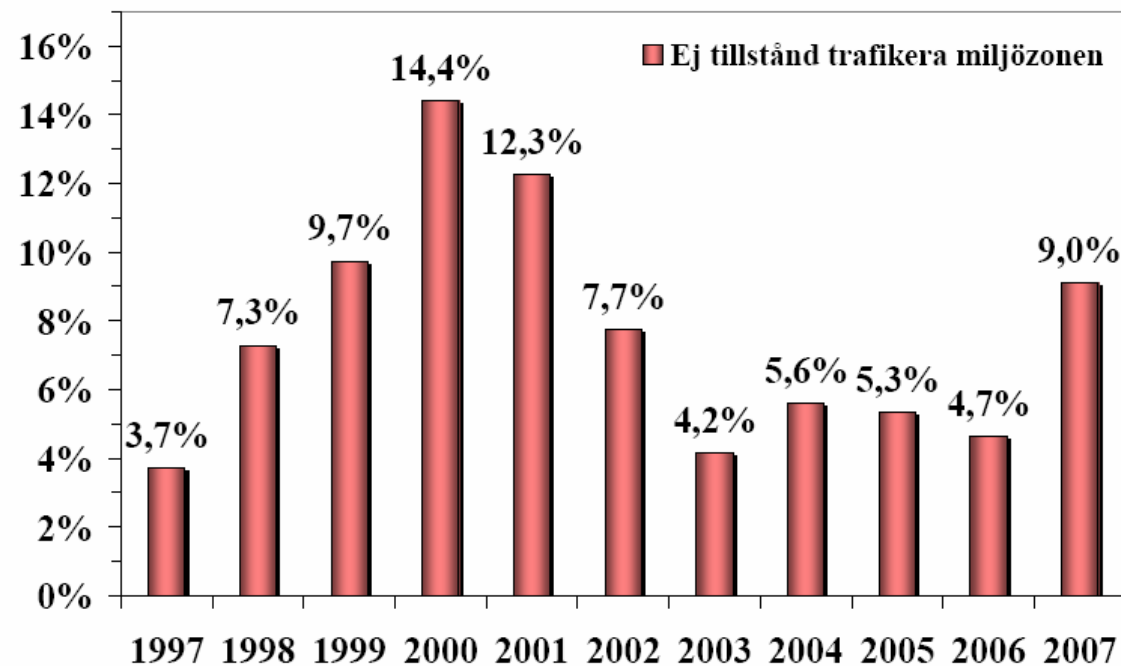
% reduction in concentrations of NO₂ & PM_{exhaust}



**Control
2007:**

**9%
illegal**

**younger
fleet than
expected**



Effect of other measures compared to congestion charge

- Higher fuel tax
 - General reduction in traffic/emissions – both exhaust & non-exhaust
 - Lower efficiency for health compared to congestion charge
- Parking: higher fees/taxes/restrictions
 - Possibly similar effects as congestion charge
- Environmental zone
 - Mainly exhaust emissions
 - PM10 EU limit still a problem
- Studded tire restrictions
 - No effect on exhaust particles
 - PM10 could be met...
- Dust binding (spring)
 - Local and short effect on high levels
 - High PM10 lowered

Thank you for your attention!

