ENVIRONMENTAL SOFTWARE AND SERVICES GMBH

Project Deliverables: D09.

Public Health Impacts

Programme name:	**Energy, Environment and Sustainable Development**
Research Programme:	**1.1.4. - 4.4.1, 4.1.1**
Project acronym:	**SUTRA**
Contract number:	**EVK4-CT-1999-00013**
Project title:	**Sustainable Urban Transportation**
Project Deliverable:	**D09.**
Related Work Package:	**WP 9 Public Health Impacts**
Type of Deliverable:	**RE Technical Report**
Dissemination level:	**RES Restricted**
Document Author:	**Cezary Orlowsky, TUG Gdansk**
Edited by:	**Kurt Fedra, ESS**
Reviewed by:	
Document Version:	**1.0**
Revision history:	
First Availability:	**2003-05-02**
Final Due Date:	**2003-06-30**
Last Modification:	**2003-06-07**
Hardcopy delivered to:	**Eric Ponthieu** DG XII-DI.4 (SDME 4/73) Rue de la Loi, 200 B-1049 Brussels, Belgium

Executive Summary

Public health impacts of urban transportation include effects directly and indirectly due to vehicular emissions; other indirect effects of the transportation system, e.g., related to crowding; and traffic accidents.

Public-health effects can reach dramatic proportions, with several thousand premature death attributed to traffic generated air pollution in European cities (Kuenzli et al, 2000): 6% of mortality or a total of 40,000 cases are attributed in France, Switzerland and Austria only, with an additional 25,000 new cases of bronchitis annually, and up to 250,000 bronchitis episodes in children, and about 0.5 million bronchitis attacks, resulting in a total of 16,000,000 person-days of restricted activities.

Traffic accidents are a growing problem. Urban areas have a higher percentage of accidents (75 %) compared to rural areas.

Using the data generated by the SUTRA case study model cascade and estimating exposure, estimates for fatalities and sick-hours were obtained with an expert system based on fuzzy logic to account for the inherent uncertainty of epidemiological data and estimates. The estimates for morbidity (expressed in sick days per year and capita) varied only slightly between scenarios. Fatality estimates varied by a factor of two between the most optimistic (CS3) and most pessimistic (CS1) scenarios. However, it seems appropriate to express these results in terms of an index measuring relative change (compared to the baseline scenario) rather than as highly uncertain absolute numbers.

Introduction

Public health impacts of urban transportation include effects directly and indirectly due to vehicular emissions; other indirect effects of the transportation system, e.g., related to crowding; and traffic accidents.

Traffic accidents are a growing problem. Urban areas have a higher percentage of accidents (75 %) compared to rural areas, but with careful planning and proper management of transportation systems, fatal accident rates can be reduced considerably. Despite their importance and staggering social costs, traffic injuries and fatalities are rarely introduced into transportation analysis. Well-defined factors can be related to the risk of injury for both vehicle occupants and pedestrians.

Risk factors that will be examined include:

- Street characteristics: pavement texture depth, lighting of main and secondary street, number of traffic conflicts, visibility and geometry of traffic system, etc
- Operational characteristics: approximation speed in both, main and secondary street, volume and traffic composition and waiting time at the secondary street, etc
- Driver perception and motor functions: vision, audition, reflex time, concentration, elevated blood alcohol, etc.

Contaminants emitted by the different kinds of vehicles (toxic gases and particles) may cause several human diseases, including:

- TSP (particles in suspension: Mucous irritation - Breathing problems;
- CO, methane: Angina - Affects pregnancies, breathing and/or cardiac problems;
- NOx (Nitrogen oxides): Bronchitis - Pneumonia;
- Pb (Lead): Affects reproductive, circulatory and nervous systems;
- HC (hydrocarbons): Eyes irritation - Sneeze - Head cold - Cancerous diseases;
- SOx (Sulphur oxides): Asthma - Bronchitis - Coughing.

Based on a relationship between contaminant exposure and health effects, the social benefits of reducing air pollution can be estimated. These dosage-response functions were used, for example, by the World Bank e.g., in Bangkok, Chile and United States (Ostro, S.S.Eskeland, Air pollution and Mortality: results from a study of Santiago,Chile. World Bank, 1994).

In public transportation in a big city, the four main factors essential to an outbreak of an air communicable disease are present: a large proportion of susceptible individuals, a disseminator, overcrowding, and lack of ventilation. In addition, sustained exposure to an infectious case may occur due to daily long bus trips (2 hours long), but repeated short periods of exposure can produce an infection. Hence, people who live in areas with a high incidence rate, and where the probability of having contact with an active case is not negligible, may become infected more often than is suspected, especially in buses where lack of ventilation is frequent during winter time. Among the air communicable diseases that will be taken into account are: Respiratory Infections (Influenza, Bronchitis, Cold, etc.); Measles; Pertussis (whooping cough); Tuberculosis.

Assessment of a transportation system must include the risk of getting an air communicable disease, evaluating the probability of contact rates and time of travel of individual bus users. Stochastic models will be used to study the risk of becoming infected. The parameters for these models would be taken from the transportation model that generates the number of persons per travel, frequency of travels, etc.

While this may be a major issues in developing countries, and wherever we find on the one hand a strong relationship between the urban poor and communicable respiratory diseases, and on the other hand a strong relationship between income and the use of usually crowded public transport, this topic was originally foreseen in relation to the case study of Buenos Aires,. With the de facto withdrawal of the Argentinian partner, it was felt that this issue is not relevant to the majority of case studies, and emphasis should instead be put on the relationship of air quality and respiratory diseases, as well as the relationship between key traffic indicators and accidents.

Modeling Public Health Impacts

The objective of the health model is to build system for forecasts the level of mortality and morbidity caused by pollution by transport. The proposed model relies on knowledge-based solutions and the theories of fuzzy sets. A detailed design of fuzzy models takes advantage of the experience of the emitted by the different kinds of vehicles (toxic gases and particles) may cause several human diseases. Data from the project participants have been utilized in tuning of the fuzzy model using knowledge-based rules and membership functions. They including:

- CO total emission [kg/h], methane: Angina - Affects pregnancies, breathing and/or cardiac problems;
- NOx (Nitrogen oxides), Max. Conc. NOx [ug/h], average [ug/h], nonzero Avg.[ug/h],: Bronchitis – Pneumonia, Cancerous diseases
- Mortality caused by pollution by transport [death in a year]
- Morbidity caused by pollution by transport [working days lost in a year]

The previously defined variables, fuzzy sets and the membership functions have been set the conditions to build the integrated model using the concept of fuzzy models. Assuming that the model is complete and the rules are continuity and compliance, the number of rules has been depended on the number of input and state variables. If we adopt the rules IF-THEN, then the number of the rules have been completed:

$$R = N^{P} = 3 * 5 = 243 \qquad (1)$$

where:
R- number of rules
N-number of fuzzy sets
p-number of input variables

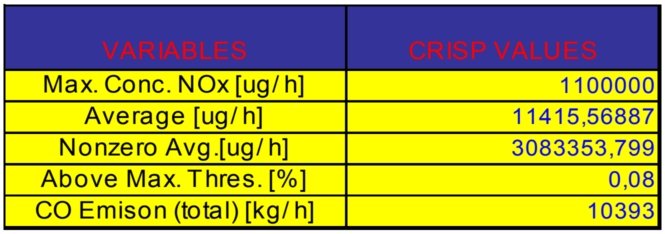
The membership function design has been based on clustering methods, where the location of cluster centers of gravity is identified allowing for adjusting the membership functions accordingly.

Fuzzy modeling

A starting point for a modeling procedure has been an mortality and morbidity evaluation of being the real system under consideration. Firstly, appropriate formal models have been developed and next, hierarchical and structural models of the relation between data concerning to the pollution and mortality and morbility have been constructed. Next, the analytical (dynamic) integrated model has been developed. In order to build a useful model, such elements of the fuzzy control theory as the fuzzy rules of the Mamdani type have been utilized, which results in vector-marix model with a fuzzy sub-system. The completeness and consistency of the fuzzy-model rules have been verified. Fuzzy-dynamic state variables have been introduced to describe the states of the management.

Input crisp value

Example of the description of crisp level (Gdansk Scenario) for membership functions has been presented in fig. 1



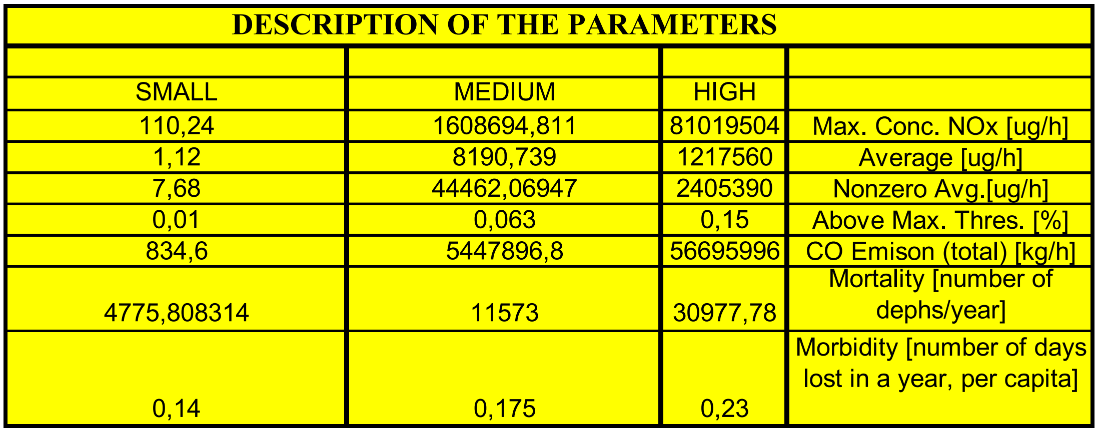
VARIABLES	CRISP VALUES
Max. Conc. NOx [ug/h]	1100000
Average [ug/h]	11415,56887
Nonzero Avg.[ug/h]	3083353,799
Above Max. Thres. [%]	0,08
CO Emison (total) [kg/h]	10393

Figure 1. GUI for input data

Description of the parameters

A clustering approach has been used in the tuning procedure by taking to the following steps: an initiation of clusters, an assignment of data (concentration and emission) to respective clusters, and an appropriate determination of the parameters of the membership function, performed with respect to:

- three fuzzy sets (low, medium, high) for each input variable,
- three fuzzy sets (low, medium, high) for each output variable



DESCRIPTION OF THE PARAMETERS			
SMALL	MEDIUM	HIGH	
110,24	1608694,811	81019504	Max. Conc. NOx [ug/h]
1,12	8190,739	1217560	Average [ug/h]
7,68	44462,06947	2405390	Nonzero Avg.[ug/h]
0,01	0,063	0,15	Above Max. Thres. [%]
834,6	5447896,8	56695996	CO Emison (total) [kg/h]
4775,808314	11573	30977,78	Mortality [number of dephs/year]
0,14	0,175	0,23	Morbidity [number of days lost in a year, per capita]

Figure 2. Example of the description of the parameters for the fuzzy sets

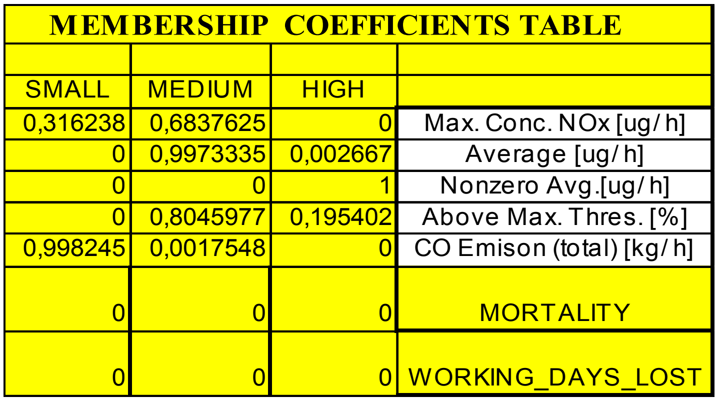
The suggested fuzzy model treats description of pollutants and examples of morbidity and mortality as a source of knowledge which may be used for carrying out the other ones. It presents the mechanism of the acquisition, implementation and use of knowledge.

Building of membership functions

On the basis of the above the total number of membership functions is 21. Please note that the state-relevant membership functions are not submitted to tuning. Thus, the quantity of the input and output variables and the number of fixed membership functions are:

$$Number\_of\_fixed\_functions = 3*5+3*2=21 \qquad (2)$$

Examples of the memberships functions (coefficients) have been presented in the figure 3



MEMBERSHIP COEFFICIENTS TABLE

SMALL	MEDIUM	HIGH	
0,316238	0,6837625	0	Max. Conc. NOx [ug/h]
0	0,9973335	0,002667	Average [ug/h]
0	0	1	Nonzero Avg.[ug/h]
0	0,8045977	0,195402	Above Max. Thres. [%]
0,998245	0,0017548	0	CO Emison (total) [kg/h]
0	0	0	MORTALITY
0	0	0	WORKING_DAYS_LOST

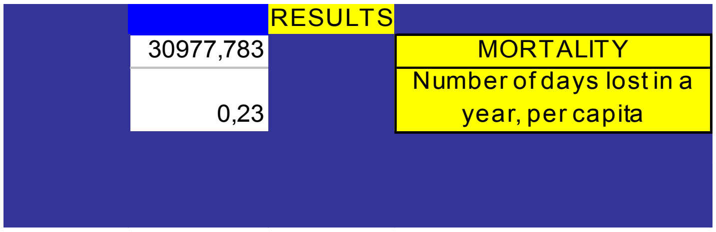
Figure 3. Examples of the memberships coefficients

Tuning the membership function

The parameters of the membership functions for the input and output variables are calculated as follows. The 'pick' values of the membership functions are placed in the cluster centers of gravity. Each fuzzy set is defined as a set of pairs, consisting of a crisp value of the respective variable (input or output) and its membership degree. The membership degree, in turn, represents a value of the membership function for this value.

Results

The health model starts off with an appropriate initiation of this decision support system and the introduction of crisp values of the input variables. Next, these crisp variables undergo a fuzzification process by computing, and the membership degrees on the basis of the respective membership functions. By using suitable inference and de-fuzzification mechanisms (based on logical operators MAX-MIN and MAX-PROD used for grouping and on the altitude method applied during calculating the crisp values), the output values, are automatically generated. Examples of the results have been presented below.



RESULTS

30977,783

0,23

MORTALITY

Number of days lost in a year, per capita

Figure.4 Examples of the output data

This model proposes a method of building rule-fuzzy mechanisms (F-R) described in an integrated model of the health has been proposed. Our presentation includes a general view of the description of its concept, formalization, the use of experimental data, as well as a method of modeling and designing a decision support system incorporating a fuzzy sub-system.

Results for the Gdansk

Input data for common and specific scenario

The input data have been included concentration of NO_x and emission of CO. Details of the input data have been presented in the table nr. 5. S means specific and C common scenarios

Table 5 Data for common and specific scenarios

		BASE	C1	C2	C3	C4	S1	S2	S3	S4
Peak concentration NOx	ug/m3	2E+06	1E+06	3E+06	939800	2E+06	1E+06	4E+06	9E+05	1453035
Average concentration Nox	ug/m3	32000	11416	13951	7041,4	10093	13982	15534	6695	8724,324
Nonzero average concentrat	ug/m3	17654	3E+06	220088	11617	9059,9	4E+06	245059	11046	7831,302
Above max. Thres.	%	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08
CO Emison (total)	kg/h	9579	10393	18343	8333	11399	7832	18123	6280	11262

The output value have been presented in the table 6

Table 6 Data for mortality and morbidity

		BASE	C1	C2	C3	C4	S1	S2	S3	S4
MORTALITY [number of dephs/year]		15365	30978	15365	15365	15365	30978	15365	15365	15364,74
MORBIDITY [number of days lost in a year, per capita]		0,186	0,23	0,1857	0,1857	0,1857	0,23	0,1857	0,186	0,185747

In the figure 1 has been presented the aggregated data for concentration and emission data per scenarios for Gdansk

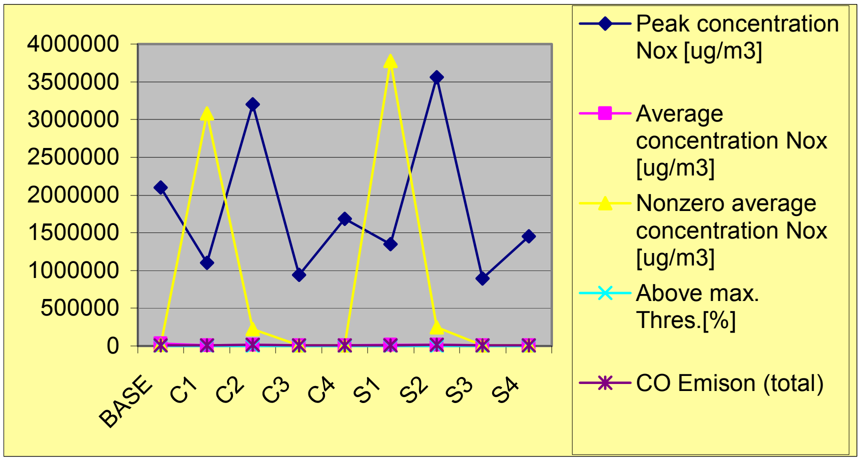


Figure 1. Concentration and emission data per scenarios for Gdansk

In the figure 2 has been presented mortality data for Gdansk and morbidity in the figure 3

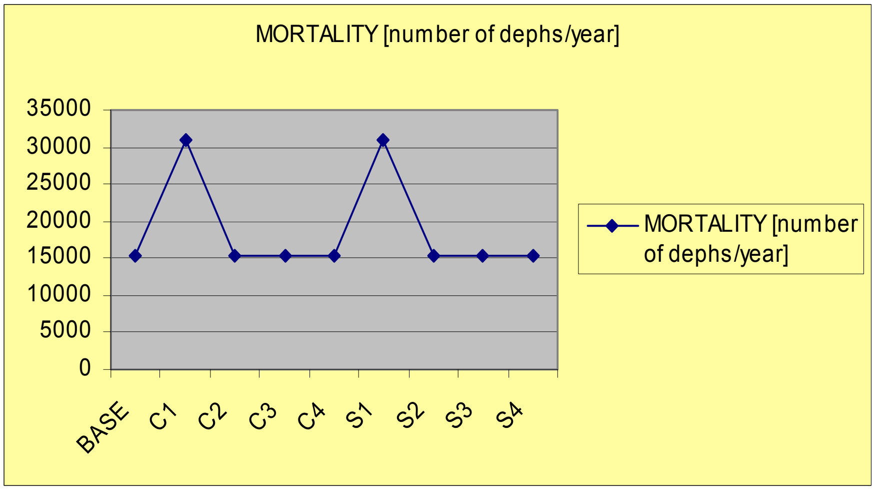


Figure 2. Mortality data per scenarios for Gdansk

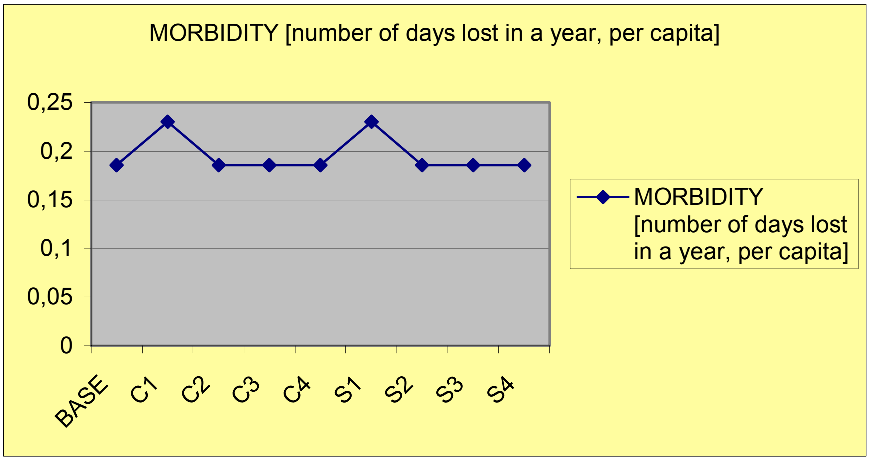


Figure 3. Morbidity data per scenarios for Gdansk

Description of results

The data obtained in Gdańsk point to the fact that both mortality and morbidity differ depending on the scenario. Mortality increases in scenario 1 for young and virtuous city and decreases in the scenarios 2, 3 and 4 . It seams to be related to the growth of the traffic volume in scenario 1a, and decrease of population in scenario 2,3, and 4, the drop in mortality is considerable which seems from adopting the strategy of the young and vicious and old city. The similar tendency may be noticed for mortality.
Gdansk health model foresees both increase and decrease of mortality and morbidity but the scope of use depends on the quantity and quantity of obtained data. In the case of Gdansk only annual data were available, thus the model's accuracy may be small as well.

Results for the Thessaloniki

Input data for common and specific scenario

The input data have been included concentration of NO_x and emission of CO. Details of the input data have been presented in the table nr. 7. S means specific and C common scenarios

Table 7 Data for common and specific scenarios

	BASE	C1	C2	C3	C4
Peak concentration Nox [ug/m3]	1E+08	123413	273321	34583	142886
Average concentration Nox [ug/m3]	3E+05	270,28	960,58	91,83	415,59
Nonzero average concentration Nox [ug/m3]	2E+06	1897,3	6571,3	651	2906,4
Above max. Thres.[%]	0,07	0,06	0,06	0,04	0,06
CO Emison (total)	1444	336328	846758	1E+05	448160

The output value have been presented in the table 8

Table 8 Data for mortality and morbidity

	BASE	C1	C2	C3	C4
MORTALITY [number of dephs/year]	30978	11188	11188	8623	11188
MORBIDITY [number of days lost in a year, per capita]	0,23	0,173	0,173	0,16	0,173

In the figure 4 has been presented the aggregated data for concentration and emission data per scenarios for Thessaloniki

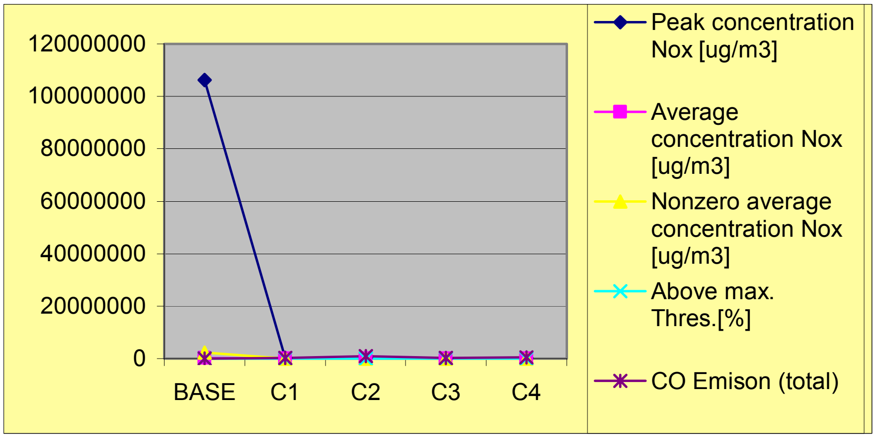


Figure 4. Concentration and emission data per scenarios for Thessaloniki

In the figure 5 has been presented mortality data for Thessaloniki and morbidity in the figure 6

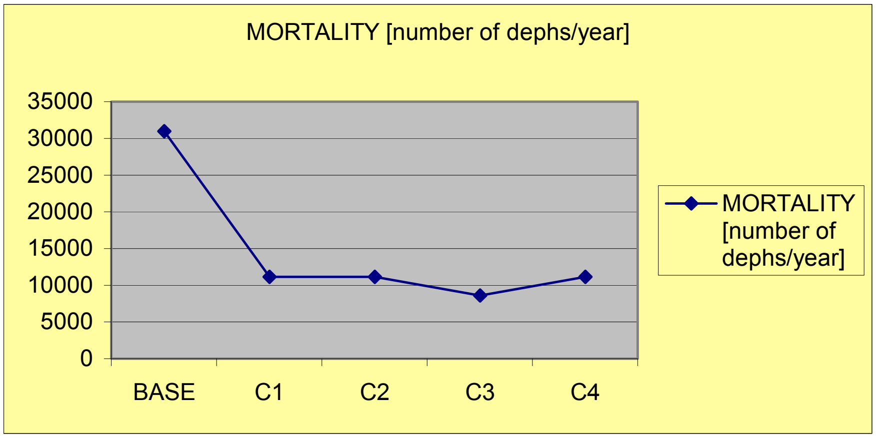


Figure 5. Mortality data per scenarios for Thessaloniki

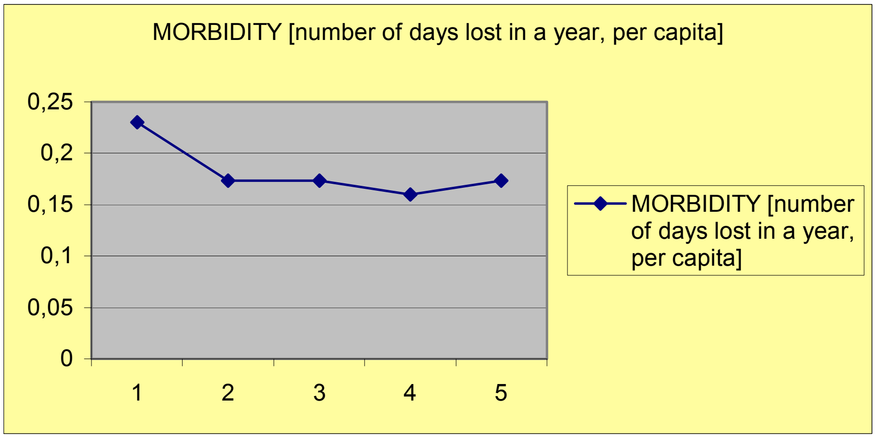


Figure 6. Morbidity data per scenarios for Thessaloniki

Description of results

The data obtained in Thessaloniki point to the fact that both mortality and morbidity differ depending on the scenario. Mortality increases in scenario 1 for young and virtuous city and decreases in the scenarios 2, 3 and 4 . It seams to be related to the growth of the traffic volume in scenario 1a, and decrease of population in scenario 2,3, and 4, the drop in mortality is considerable which seems from adopting the strategy of the young and vicious and old city. The similar tendency may be noticed for mortality.

For Thessaloniki case model use of general data for the country not for the city, but there were no results of the research considering mortality and morbidity

Results for the Lisbon

Input data for common and specific scenario

The input data have been included concentration of NO_x and emission of CO. Details of the input data have been presented in the table nr. 9. S means specific and C common scenarios

Table 9 Data for common and specific scenarios

	BASE	C1	C2	C3	C4
Peak concentration Nox [ug/m3]	8E+07	982,22	8124,1	1197	3382,6
Average concentration Nox [ug/m3]	1E+06	11,11	91,83	12,74	35,11
Nonzero average concentration Nox [ug/m3]	2E+06	14,93	123,39	17,22	47,16
Above max. Thres.[%]	0,15	0,07	0,07	0,07	0,07
CO Emison (total)	5E+07	958,9	17803	1014	4945,8

The output value have been presented in the table nr 10

Table 10 Data for mortality and morbidity

	BASE	C1	C2	C3	C4
MORTALITY [number of deaths/year]	30978	13134	13134	13134	13134
MORBIDITY [number of days lost in a year, per capita]	0,23	0,1794	0,1794	0,179	0,1794

In the figure 7 has been presented the aggregated data for concentration and emission data per scenarios for Lisbon

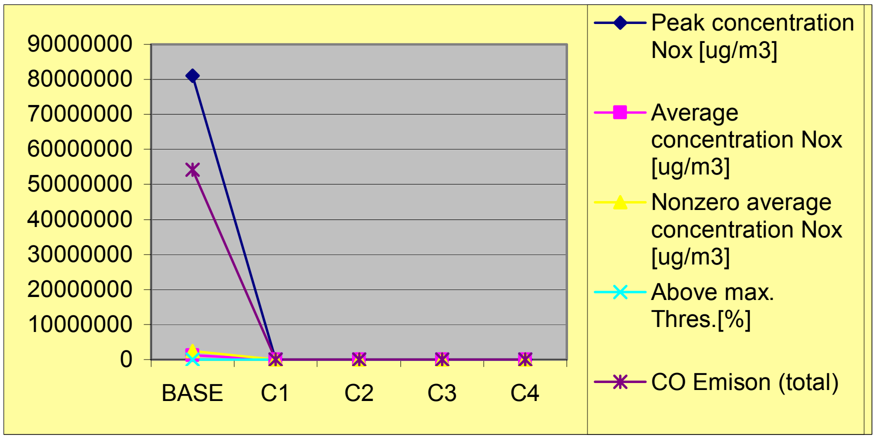


Figure 7. Concentration and emission data per scenarios for Lisbon

In the figure 8 has been presented mortality data for Lisbon and morbidity in the figure 9

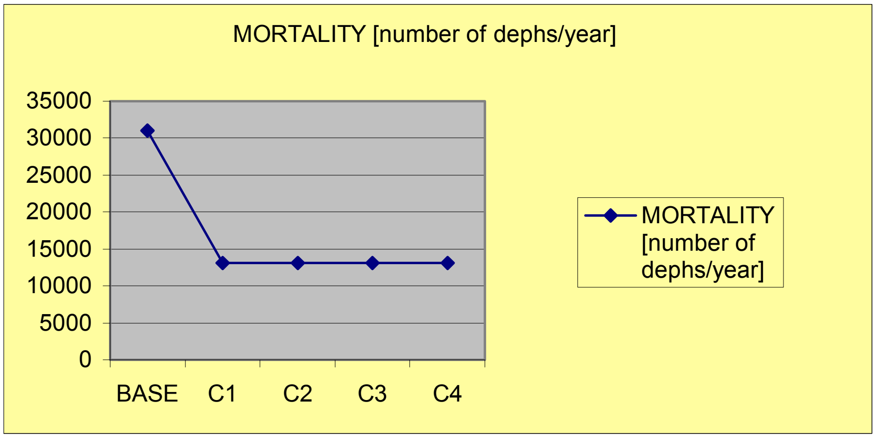


Figure 8. Mortality data per scenarios for Lisbon

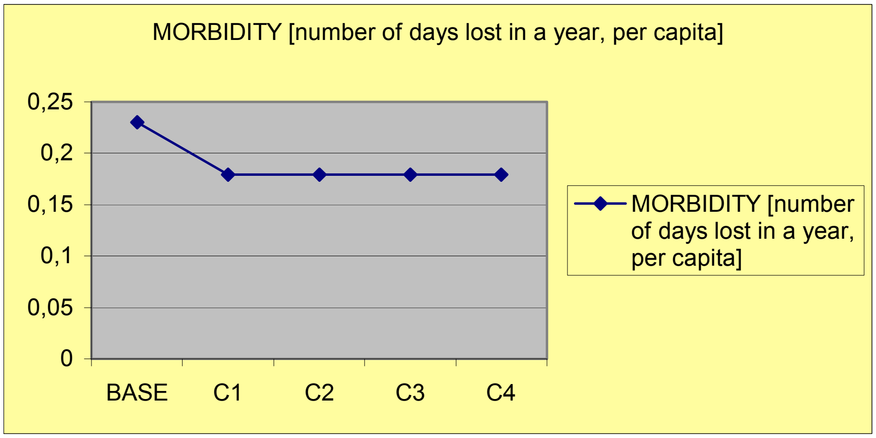


Figure 9. Morbidity data per scenarios for Lisbon

Description of results

The data obtained in Lisbon point to the fact that both mortality and morbidity differ depending on the scenario. Mortality increases in scenario 1 for young and virtuous city and decreases in the scenarios 2, 3 and 4 . It seams to be related to the growth of the traffic volume in scenario 1a, and decrease of population in scenario 2,3, and 4, the drop in mortality is considerable which seems from adopting the strategy of the young and vicious and old city. The similar tendency may be noticed for mortality. For Lisbon case model use of general data for the country not for the city, but there were no results of the research considering mortality and morbidity

Results for the Genoa

Input data for common and specific scenario

The input data have been included concentration of NO_x and emission of CO. Details of the input data have been presented in the table nr. 11. S means specific and C common scenarios

Table 11 Data for common and specific scenarios

	BASE	C1	C2	C3	C4
Peak concentration Nox [ug/m3]	830,1	3530.22	4E+06	6167	110,24
Average concentration Nox [ug/m3]	4,5	23,67	33699	22,49	1,12
Nonzero average concentration Nox [ug/m3]	47,89	162,8	231812	153,9	7,68
Above max. Thres.[%]	0,08	0,05	0,05	0,01	0,14
CO Emission (total)	82700	16971	4360,1	37219	834,6

The output value have been presented in the table nr 12

Table 12 Data for mortality and morbidity

	BASE	C1	C2	C3	C4
MORTALITY [number of deaths/year]	15365	30978	13113	4821	28747
MORBIDITY [number of days lost in a year, per capita]	0,186	0,23	0,1794	0,14	0,2237

In the figure 10 has been presented the aggregated data for concentration and emission data per scenarios for Genoa

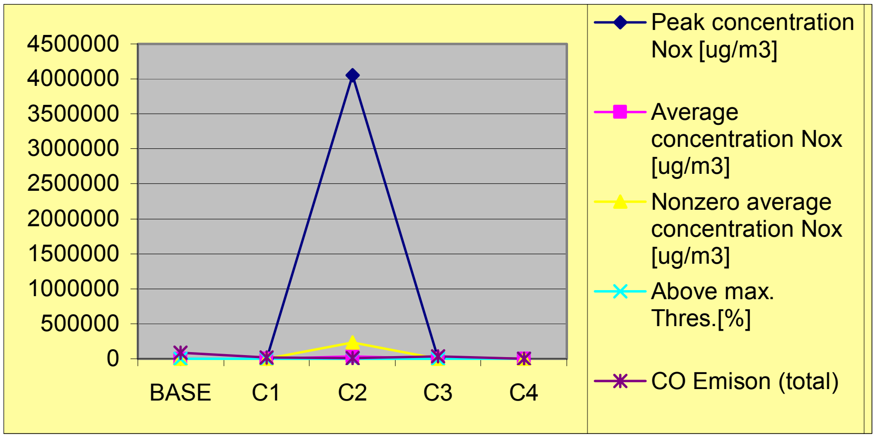


Figure 10. Concentration and emission data per scenarios for Genoa

In the figure 11 has been presented mortality data for Genoa and morbidity in the figure 12

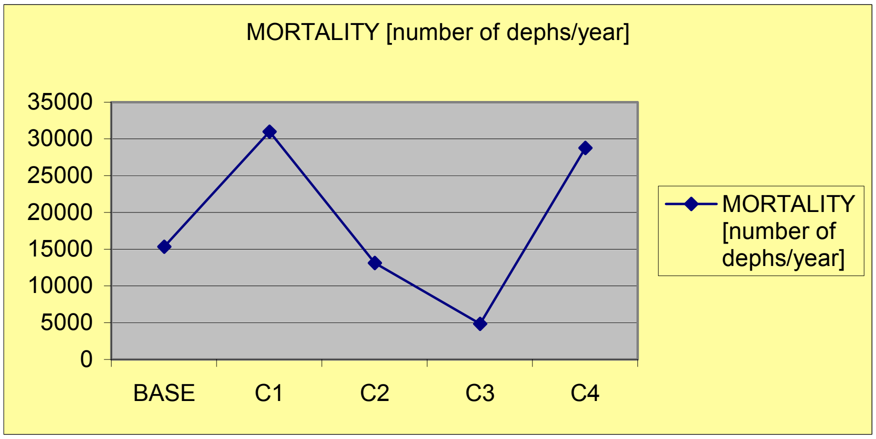


Figure 11. Mortality data per scenarios for Genoa

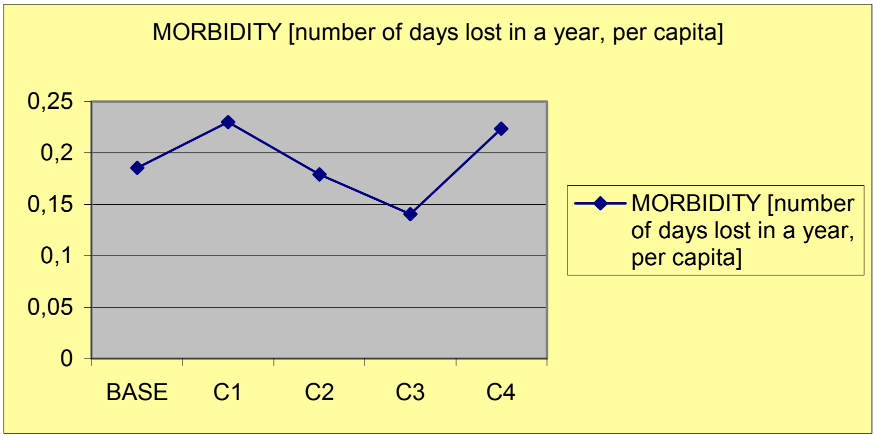


Figure 12. Morbidity data per scenarios for Genoa

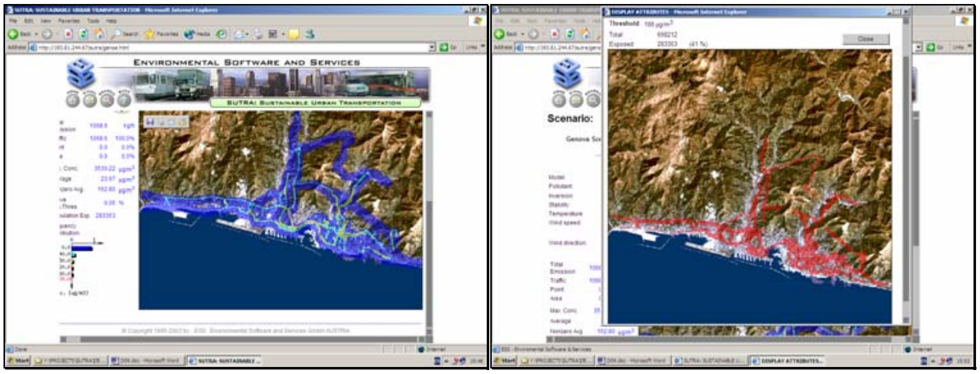
Description of results

The data obtained in Genoa point to the fact that both mortality and morbidity differ depending on the scenario. Mortality increases in scenario 1 and 4 for young and virtuous city and decreases in the scenarios 2, 3 different for other cities. It seams to be related to the growth of the traffic volume in scenarios 1 and 4, and decrease of population in scenario 2,3 , the drop in mortality is considerable which seems from adopting the strategy of the young and vicious and old city. The similar tendency may be noticed for mortality.

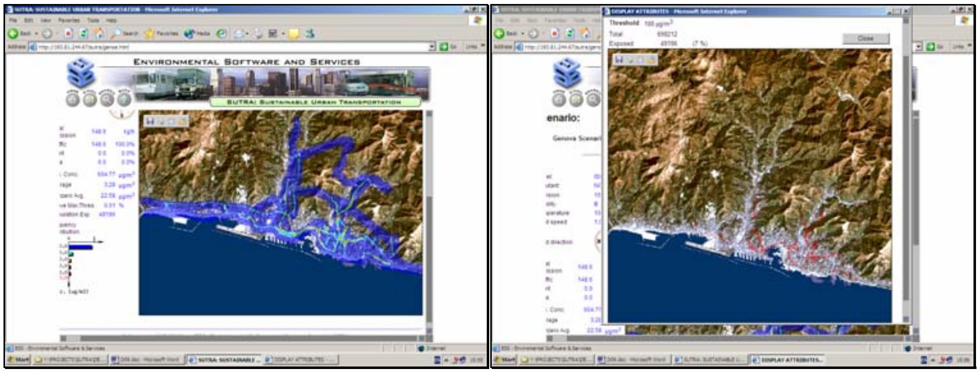
For Genoa case model use of general data for the country not for the city, but there were no results of the research considering mortality and morbidity

Comparison with population exposure estimates

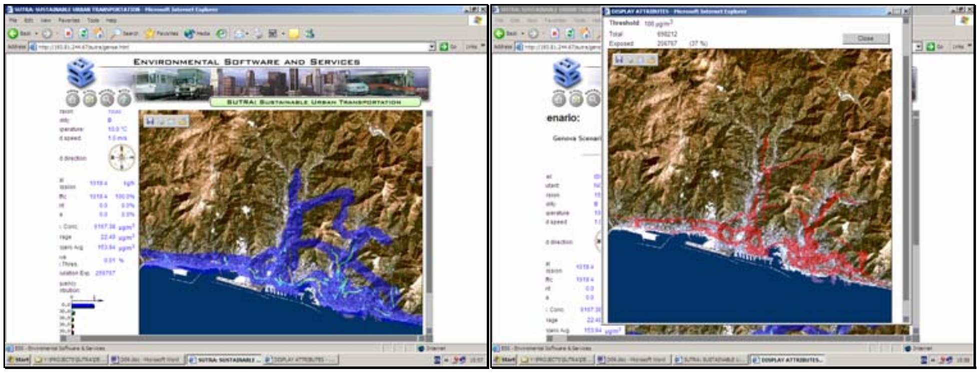
The estimates from the expert systems can be directly compared with the results from the city level air quality modelling, which in a post-processing step estimates population exposure above an arbitrary air quality threshold for the comparison of environmental and public health impacts of the different scenarios. The examples below compare the results for Genoa:



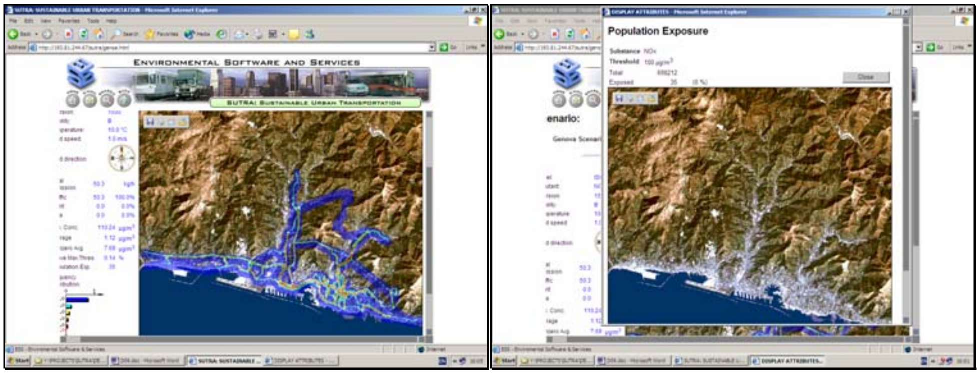
Baseline scenario: 41% 283,353



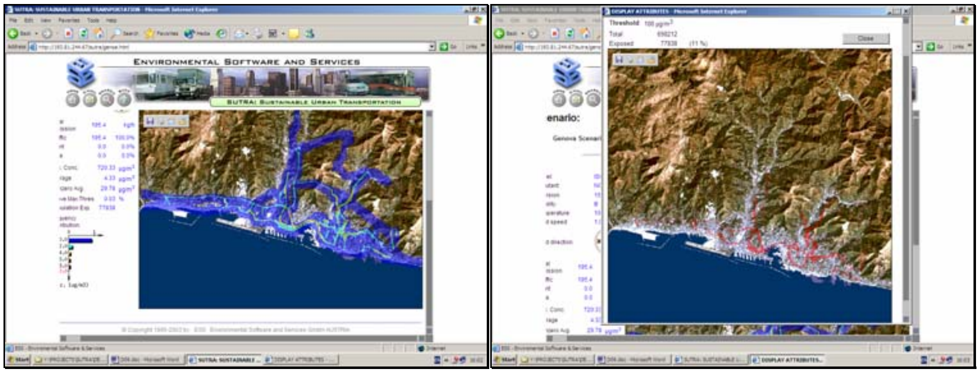
Common scenario 1, Dynamic,rich and virtuous: 7%, 49,196



Common scenario2, Dynamic, rich and vicious: 37%, 256,767



Common scenario 3, Virtuous pensioners: 0%, 35



Common scenario4, Vicious pensioners, 11%, 77,838

Results for the TelAviv

Input data for common and specific scenario

The input data have been included concentration of NO_x and emission of CO. Details of the input data have been presented in the table nr. 13. S means specific and C common scenarios

Table 13 Data for common and specific scenarios

	BASE
Peak concentration Nox [ug/m3]	1E+07
Average concentration Nox [ug/m3]	37112
Nonzero average concentration Nox [ug/m3]	2E+05
Above max. Thres.[%]	0,08
CO Emison (total)	6E+07

The output value have been presented in the table 14

Table 14 Data for mortality and morbidity

	BASE
MORTALITY [number of deaths/year]	30978
MORBIDITY [number of days lost in a year, per capita]	0,23

Description of results

It is difficult to describe the results only for base scenario. We received from the city the mortality 620. The results form the model and from the city are different and not to be assessed.

Results for the Geneva

Input data for common and specific scenario

The input data have been included concentration of NO_x and emission of CO. Details of the input data have been presented in the table nr. 15. S means specific and C common scenarios

Table 15 Data for common and specific scenarios

	BASE
Peak concentration Nox [ug/m3]	8226
Average concentration Nox [ug/m3]	22
Nonzero average concentration Nox [ug/m3]	101,8
Above max. Thres.[%]	0,08
CO Emison (total)	87559

The output value have been presented in the table 16

Table 16 Data for mortality and morbidity

	BASE
MORTALITY [number of dephs/year]	15365
MORBIDITY [number of days lost in a year, per capita]	0,186

Description of results

It is difficult to describe the results only for base scenario.

References

Kuenzli et.al (2000) Public-health Impact of outdoor and traffic related air pollution: a European assessment. The Lancet, Vol. 356, Sept. 2000, 795-801