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ROADAIR 2.0

User's Manual

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PREFACE

This is the User's Manual for RoadAir 2.0, which is a PC-based model for air pollution along a network of roads. The model has been developed for Norwegian conditions. In most cases, it may be possible to adapt RoadAir to the conditions in other countries by some modifications in the programming code (different air quality guidelines etc.).

Steinar Larssen and Frederick Gram at NILU have developed the original RoadAir version at NILU, finished in 1989. Since then the following people have also contributed to the further development: Jan Sørlie, Dag Tønnesen and Charlotte Torp (NILU), Sidsel Kålås and Kristin Strand (Directorate of Public Roads) and Jens E. Thyholdt (Asplan Tønsberg A/S).

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ROADAIR, VERSION 2.0

USER'S MANUAL

1 INTRODUCTION

A model called RoadAir has been developed as a PC programme at the Norwegian Institute for Air Research. It is used for calculating emissions, concentrations and exposure of the population to air pollution along defined road networks. The programme may also be used to investigate pollution along single road links, but has not been developed with this in mind. RoadAir has to a large extent been developed to suit the needs of the Directorate of Public Roads in Norway, in connection with their transport planning activities.

The emission calculations are based on emission matrices given in the Nordic Method for Car Exhaust Pollution (NMR, 1984). These matrices have been modified to account for road gradients and changes in emission factors due to renewal of the vehicle fleet.

For roads in open areas, concentrations are calculated by the use of a modified version of the EPA model HIWAY 2. For roads enclosed within facades ("streets canyons"), the Nordic Method mentioned above is used.

The model is under continuous development, and the emission factors will be revised in the near future. According to the plan, the version 3.0 will be published during the Autumn 1993.

This user's manual describes briefly the methods used in RoadAir. For more detailed information, a documentation report in English is being worked out.

2 WHAT IS CALCULATED BY ROADAIR?

- Emissions of CO, NO_x and CO_2 from the traffic on each road link, as well as from the entire network. It is possible to calculate separately the emissions from

  . light duty vehicles,
  . heavy duty vehicles,
  . and buses.

Rougher estimates can be made on extra emissions from road intersections and roads not included in the defined road network.

Emissions are given separately for three city zones (outskirts, intermediate areas, and central areas). The calculated CO_2 emissions also include CO, since CO eventually is converted to CO_2 in the atmosphere. Table 1 gives an example of CO-emissions from main roads in the Rogaland area in Norway in 1998.

Table 1: Total emissions as presented by RoadAir. Example: CO from roads in the area of Rogaland. Similar tables for NO_x and CO_2 are given in the result file.
Road intersect. = Emission from road intersections.
Low traffic = Emission from low-traffic roads, not included in the defined road network. (These emissions are set to zero in this example).

	Emission of CO (carbon monoxide) (tonnes/year)			
	Outskirts	Intermediate	Central	Total
Light vehicles	293.6	1 398.1	3 956.9	5 648.6
Heavy vehicles	13.3	40.5	122.4	176.2
Buses	1.0	3.7	7.2	11.9
Subtotal	307.8	1 442.4	4 086.4	5 836.6
Road intersect.	51.2	103.4	361.4	516.0
Low traffic	0.0	0.0	0.0	0.0
Total	359.0	1 545.8	4 447.8	6 352.6

- Concentrations of CO and NO_2 at a chosen distance from the curb, for each road link. In street canyons the concentrations are calculated at the building facades. Along roads in open areas, the user chooses the distance from the curb to the point of calculation uniformly for the whole road network. The concentrations represent the maximum hourly value that is expected to occur, and are valid along the parts of the road links which are not affected by intersections. How far away from an intersection you need to be for the model to be valid, depends among others on the length of the quing zones.

  The number of road links and the length of roads within four concentration classes for CO and NO_2 are calculated. In the RoadAir 2.0 version, these classes correspond to the various air quality guidelines given by Norwegian authorities as shown in Table 2. The programming code may be altered to fit other national guidelines, e.g. the EEC air quality guidelines.

Table 2: Classification in concentration classes for CO and NO_2.

Pollution class	CO		NO_2	
	Concentration interval (mg/m^3) Hourly values	Norwegian Air Quality Guidelines that are exceeded	Concentration interval ($\mu g/m^3$) Hourly values	Norwegian Air Quality Guidelines that are exceeded
Severe	>25	1 hour average of 25 mg/m^3	>350	1 hour average of 350 $\mu g/m^3$
Intermediate	15-25	8 hour average of 10 mg/m^3	200-350	1 hour average of 200 $\mu g/m^3$
Little	8-15	-	130-200	24 hour average of 100 $\mu g/m^3$
Minute	0- 8	-	0-130	-

- Road dust deposition ($g/m^2 \cdot month$) along each road link, classified from 1 to 4 as shown in Table 3. The model is valid for the dry part of the winter season in areas where studded tyres are used extensively during winter, such as in Norway. The number of road links and the length of the roads in the four road dust classes are given, for the three city zones.

Table 3: Classification for road dust deposition.

Road dust deposition class	1	2	3	4
Rate of deposition (g/m^2*month)	<5	5-10	10-20	>20

- Population exposure to CO and NO_2, given as the number of people exposed in four concentration classes in each area type. The concentrations are calculated at the facades of buildings where people live, 3 m above ground level.

- Nuisance from air pollution as it is experienced by people in their homes. "Nuisance" is presented as the number of people severely bothered by air pollution (smell and dust) from road traffic in each area type. This part of the model has considerable uncertainty, especially for future situations. We have defined a parameter which is meant to express the nuisance due to the combined effect of smell and dust/filth. A health investigation carried out in Oslo of people's experience of nuisance as a function of concentration levels of NO_2 has been used as a background for this module (Samferdsel, 1991).

3 INPUT DATA

3.1 FLEXIBILITY VERSUS SIMPLICITY

RoadAir is run interactively. The programme reads input data from

- a file with data describing road links and traffic, and
- a file with data describing the position of buildings, and
- the computer terminal, by user dialogue.

When designing the model, we had to decide which parameters could be specified in the input files, and which should be given by user dialogue. The need for simplicity of running the programme speaks for limiting the user dialogue, but this would reduce the flexibility of the model. On the other hand, if all the input data were given by user dialogue, one could easily investigate the effect of varying each parameter, but it would not be practical to run the model for large road networks. (Models constructed to investigate concentrations on single road links are more suited to user dialogue only.)

We have chosen to let the user give the following parameters during programme execution:

- Year of computation. The traffic data are given for the year in question. The changes in the vehicle fleet, relevant to emission changes, is built into the model, valid for the Norwegian car fleet.

- Background concentrations. In this case, the "background" means city background, i.e. the contribution to the concentrations in the street originating from all other emissions except the emissions from the traffic in the street itself. The background levels are often not well known, and it may be useful to carry out calculations for varying background levels. By assuming zero background level, the contribution from the roads can be found separately.

- Introduction of some specified new emission regulations.

- Distance between the curb and point of concentration calculation.

- Whether to add the emissions from roads in the calculation area which are not included in the defined road network. In many cases only the main road network will be defined on the input files. Based on certain assumptions, it is possible to add emissions from the remaining roads.

- Whether population exposure should be calculated, which is possible only if a building register is available.

- The number of residents per building unit, as average for all buildings.

- Whether road links shall be ranked in the output file according to falling concentrations of CO or NO_2 .

3.2 GENERATING INPUT FILES. ERROR MESSAGES

There exists a system for registering input data for air pollution and noise calculations, called VADM. It has been developed by the company Asplan in Tønsberg. In this system, the programme VREG may be used to generate the input files needed by VLUFT, from data existing on ASCII-format. The VADM system is not at present available in English. Input files may also be generated "manually" by use of an editor, according to the description in paragraph 3.3.

If one or more parameter(s) are placed in wrong positions, or have values of no meaning to the programme, this will in most cases only affect the road link in question. The most common errors are tested for, and error messages will be written to

the file RoadAir.err. (see Chapter 6). In some cases, errors in the input data may cause programme termination, e.g. if division by zero is attempted during execution.

If there is an empty space in a column where the programme expects a value, this is read as zero. Some parameters are assigned standard values if they have zero value in the input file, as described in the next chapter.

The input file is read line by line. No data is interpreted as input data until a line is reached where the first five positions contain the word start/Start/START. The lines above this point may be used for comments. Data are read until the limit of 2000 road links is reached, or the end-of-file sign appears. Characters other than "blank" or a number in position 1 on a line, is interpreted as end-of-file.

3.3 DESCRIPTION OF INPUT FILES

3.3.1 Road and traffic data

Table 4 below contains a list of the road and traffic data needed, whether the number should be given as an integer or a real number, the number of spaces assigned to each parameter and its position on the line. The numbers should be aligned to the right within the given position intervals. In the case of real numbers given with a decimal point but no decimals (e.g. 24.) the decimal point counts as one position, and should be adjusted to the right.

Table 4: Road and traffic data.

Parameter, abbreviation	Position on a line	Integer-I Real-R Arbitrary character - A	Range, if any	Max. No. of digits
Road link number, LNR	1- 5	I		5
Road link identity	7- 27	A		20
Road intersection type, starting point of a link, KT FROM	37- 38	I	0- 2	
Road intersection type, end point of a link KT TO	48- 49	I	0- 2	
Road class, GKL	88- 89	I	1- 5	
Road width, KB	92- 96	R		5
Distance curb-facade, FA	99-103	R		5
Gradient of the road, ST	106-110	R		5
Length, L	113-119	R		7
Direction, RE	122-123	I	0- 2	
Area type, OTY	126-127	I	1- 3	
Facade coverage, FD	130-131	I	1- 6	
Fraction of heavy duty traffic, TA	134-138	R	0-100	
Average daily traffic, ADT	141-148	R		8
Average velocity, V	151-155	R		5
Average daily traffic, buses, ADT-B	158-163	R		6
Rush hour traffic, Mmaks	165-172	R		7
Rush hour velocity, Vmaks	175-179	R		5
Rush hour TA, Tmaks	182-186	R	0-100	
Rush hour traffic, buses, Bmaks	189-193	R		5

In the following, each of the parameters are specified in more detail.

Road link number, LNR, is used to identify each link, and may be given values from 1 to 99999. It is not necessary for the links to be given in numerical order on the input file. The maximum number of links is 2000. All the parameters in table 4 should be uniform along each road link.

Road link identity, (name, number, etc) may be specified by use of the 20 spaces meant for this purpose. All signs, characters and numbers may be used, since this parameter is read as a character string.

Road intersection type KT FROM, KT TO at the start and end points of a road link. This is used for calculating additional emissions caused by retardation, acceleration and idling near road intersections. The types included in the model are:

0 - no intersection, or intersection without traffic light
1 - traffic light
2 - roundabout

Road width, KB, should be given in meters, as distance between the roadway curbs.

Distance curb-facade, FA, should be given in meters, as distance from the curb to the facade of the adjacent building, in cases where FD = 1 or 2. If FD = 2, the distance to the closest building should be used.

Gradient of the road, ST, is given in percent. ST is only accounted for if the road has one way traffic (RE = 1 or RE = 2). The maximum gradient allowed in the model is 12%.

Length, L, given in meters.

Direction, RE. To-way traffic: 0. One-way traffic: 1. One-way traffic in the opposite direction:2.

Road class, GKL, describes the function of the road. Except for GKL = 5, the classification used in RoadAir corresponds to the Nordic Method for Calculation of Exhaust Pollution (NMR, 1984).

1: Main road/through fare road.
Main road leading towards the city centre, leading through the centre or ringroad passing through semicentral area. The traffic intensity reaches distinct maximum values during morning and afternoon rush hours. Large fraction of heavy duty traffic.

2: Main road in central city area.
The road takes local traffic within the central areas of the city or town. The traffic intensity is more evenly distributed over the day than for GKL = 1. The driving mode along a GKL = 2 may be uneven, with frequent disturbances causing acceleration/retardation. Lower fraction of heavy duty traffic, unless the number of buses is very high.

3: Main road in residential area.
Road directing traffic from/to GKL = 1, to/from one or more residential areas. The traffic distribution is characterized by maximum intensity during rush hours, and the fraction of heavy duty traffic is low.

4: Main road in industrial area.
Road leading traffic to and from a major industrial complex. The fraction of heavy duty traffic is high.

5: Local road in residential area.
Traffic intensity distribution and fraction of heavy duty traffic similar to GKL = 3. Uneven driving mode.

As can be seen, this classification is adapted to cases where the calculation area is a city or urbanized area. RoadAir has frequently been used in cases where the calculation area includes both urban areas, rural areas and major motorways in the same road network. Motorways belong to GKL = 1, and the remaining roads in rural areas can often by classified as GKL = 1 or GKL = 5.

The road class parameter is used for assigning values for cold start fraction (see Table 8). If no value for Mmaks or TA is given on the input files, standard values are assigned as a function of road class (see Tables 5-6).

Area type, OTY, is used for assigning a value for background pollution to each road link, and is also used in the assignment of cold start fraction. The types are:

1: Sparsely built-up areas/rural areas,
2: medium built-up areas/outskirts of towns/residential areas/ suburbs,
3: central urban areas, often with continuous facades.

The main point when classifying the network into area types is not the density of population in itself, but that the OTY classification reflects the variation in the background pollution.

Facade coverage, FD.

1: Continuous facades along one side of the road, length above 75 m, assuming FA < 15 m.

2: Continuous facades along both sides of the road, length above 50 m, assuming FA < 15 m.

3: Scattered buildings and/or vegetation.

4: Open area (including bridges).

5: Special topography, e.g. steep hill, high wall.

6: Tunnel.

For FD = 1 and 2, the dispersion model from the Nordic Method (NMR, 1984) is used. For FD = 3, 4 or 5, a modified version of HIWAY 2 is used. For FD = 5, the calculation results should be considered separately. For FD = 6, concentration values of CO = 99.0 mg/m^3, NO_2 = 999.0 mg/m^3 and Road Dust class 4 are assigned. This is done to indicate high pollution levels. RoadAir is of cource not a valid model for tunnels.

Fraction of heavy duty traffic, TA, given as percent of the total traffic volume (vehicles weighing more than 3.5 tonnes). If no value for TA is given on the input file, the default values given in Table 5 will be used. TA has a major impact on

concentration and dust calculations, and it is essential that the values assigned are as realistic as possible. In most countries there is, however, a lack of traffic models for the heavy duty traffic.

Table 5: Standard values of TA as a function of GKL.

Street class (GKL)	TA (%)
1	10
2	6
3	4
4	12
5	6

Annual average daily traffic, AADT, given as vehicles per 24 hours.

Driving velocity, V, in km/h. The weighted average vehicle speed should be used.

Average daily bus traffic, ADT-B, given as number of buses per 24 hours. The bus traffic must be included in TA. The reason for having a separate parameter for bus traffic is to be able to calculate the emissions from this kind of public transport separately.

Rush hour traffic, Mmaks. The maximum expected hourly traffic, given as vehicles per hour. If no values are given, the programme uses the default values of Table 6.

Table 6: Default values for Mmaks as function of road class.

Road class (GKL)	Mmaks (%)
1	10
2	8
3	10
4	10
5	8

Velocity during rush hour, Vmaks, given in km/h. If no value is given, Vmaks is set equal to V by the programme. Vmaks is the basis for the concentration calculations, and it is therefore of great importance that correct values are assigned.

Table 7 shows some suggested values for Vmaks of city streets which may be used if no data on this are available and the user feels unable to make qualified guesses.

Table 7: Suggested values of Vmaks in cases where its value is unknown.

Road Class (GKL)	Vmaks (km/h)	
	Street with traffic below its capacity limit	Street with traffic intensity that has reached the capacity limit
1	45	30
2	40	30
3	45	35
4	50	40
5	40	30

Fraction of heavy duty traffic during rush hours, Tmaks, given in percent. If no value is given, TA is used as default by the programme. However, most often Tmaks will be lower than TA because the rush hour traffic is more dominated by light duty vehicles.

Bus traffic during rush hours, Bmaks, equals the maximum number of buses per hour during a day. If no value is given, Bmaks is set equal to zero.

Figure 1 shows example of an input file.

VREG V L U F T - d a t a

LNR	NAVN	KT FRA	KT TIL	GKL	KB	FB	ST	L	RE	OTY	FD	TA	ÅDT	V	ÅDTB	MMAKS	VMAKS	TMAKS	BMAKS
Start																			
1	EV 125862978	1	0	1	15.	0.	0.	230.	0	3	4	10.	26600.	60.	0.	0.	0.	0.	0.
2	RV 806295836	0	1	1	7.	0.	0.	240.	0	2	3	0.	11000.	50.	0.	0.	0.	0.	0.
3	RV 284597310	0	0	2	7.	0.	0.	220.	0	2	3	0.	10500.	50.	0.	0.	0.	0.	0.
4	RV 795168437	1	0	2	7.	0.	0.	980.	0	1	6	5.	9700.	50.	0.	0.	0.	4.	0.
.																			
.																			
.																			
400	EV 158947265	0	1	2	7.	0.	0.	110.	0	1	3	7.	7800.	50.	70.	0.	0.	0.	0.
403	EV 458726511	0	0	2	7.	0.	1.	140.	0	1	3	0.	6000.	50.	70.	0.	0.	0.	0.
403	RV 581436967	0	0	2	7.	0.	1.	140.	0	1	3	0.	2000.	50.	70.	0.	0.	0.	0.
430	RV 745296362	0	0	2	7.	0.	0.	110.	0	1	3	0.	2000.	50.	70.	0.	0.	0.	0.

Figure 1: Input file with road and traffic data.

3.3.2 Data on buildings

All buildings within 100 m from the curb on each side of the road should be included in the register. As in the road/traffic file, all lines above the one with start/Start/START in the 5 first positions are interpreted by the programme as comments. The model needs 3 pieces of information for each building from the building file, to be able to calculate the air pollution exposure of the population:

- Number of residential units (position 66-67)
- Road link number corresponding to the building (pos. 73-77)
- Distance from the centre of the road to the building facade (pos. 85-87)

The reason for reading data from these positions on the file, is that prior to the development of RoadAir, there already existed building registers that had been constructed by Norwegian Road Authorities for noise calculations. These contain a lot more data than is needed for the air pollution calculations.

The number of residents per unit is given as part of the user dialogue.

4 RESULTS

Having run RoadAir 2.0, the calculation results will be written to the file that has been specified by the user. The file contains the following data:

1. Date and time of calculation.
2. Name of file with road and traffic data.
3. Name of output file.
4. Year of calculation.
5. Tables with total emissions of CO, CO_2 and NO_x in tonnes/year. Emissions are given separately for light vehicles, heavy duty vehicles, buses, road intersections and low traffic roads. For each of these sources, emissions are given separately for the central, intermediate and outskirt areas.
6. Table giving traffic activity (km/24 hrs) for the different area types and vehicle classes.
7. Background concentration values used.
8. A list of the concentration intervals represented by the various pollution classes.
9. The number of residents per housing unit, and the resulting total number of people in the calculation area.
10. Table giving the number of persons exposed to various concentrations of CO, for the various area types (central, intermediate, outskirt).
11. Similar table for NO_2.
12. Table with the number of people severely bothered by air pollution, for each area type.
13. The total length of the defined road network, and the total number of road links.

14. The number of links and length of road which is made up of tunnels.
15. Table containing the length of road and number of road links in various concentration intervals for CO and NO_2. The concentrations are valid for the given distance from the road curb, selected by the user, uniformly for the whole road network.
16. Table containing the road length and number of road links in four classes for road dust deposition, for each area type.
17. Table containing for each road link:
    - some of the data from the input file (length, traffic, heavy duty fraction, velocity)
    - emissions of CO, CO_2, NO_x
    - number of persons exposed to average concentrations above the guidelines
    - number of people severely bothered by air pollution.

5 DESCRIPTION OF SOME OF THE PROGRAMME MODULES

5.1 STRUCTURE OF RoadAir

RoadAir is to a certain extent programmed in an "object-oriented" way; it is made up of modules that may be altered, without affecting the rest of the programme. The modules are:

- emissions
- dispersion
- background pollution
- exposure
- road dust
- nuisance

Concentrations and exposure to CO and NO_2 are calculated on the basis of emissions, dispersion and background pollution. Road

dust deposition is calculated from traffic activity. Nuisance is calculated from NO_2 concentrations. The modules are thus interrelated.

5.2 EMISSIONS

5.2.1 The defined main road network

RoadAir calculates emissions of CO, CO_2, and NO_x from the road network.

CO_2 emissions are calculated from traffic activity, converted to fuel consumption. Emissions of CO and NO_x are calculated as follows:

The traffic activity (vehicles/h) on each road link is multiplied by an emission factor (g/km), which is a function of vehicle speed, vehicle class, cold start fraction and gradient of the road. Fraction of cold engines as a function of road class is shown in table 8. Calculation of total emissions is based on average velocity during the day. Rush-hour emission calculations are used as input to calculate concentrations.

It is assumed that the specific fuel consumption for light vehicles will be reduced by 20% from 1989 to 2005. For heavy duty vehicles the assumed reduction is 17%, and for buses 25%.

The rate of replacement of the vehicle fleet is set to 7% per year. All new petrol driven light duty vehicles, introduced after 1989, are equipped with a 3-way catalyst according to Norwegian regulations. We assume that vehicles equipped with a catalyst in the warm engine phase emit 10% of the CO and NO_x emitted from a warm car without a catalyst.

Table 8: Percentage of cold engines as a function of road class and area type (OTY).

Road class		Morning traffic	Afternoon traffic	24 hr average
1		25	25	25
2		15	40	25
3		40	15	25
4		15	25	25
5	OTY=1	5	5	5
	OTY=2	25	25	25
	OTY=3	40	15	25

Emission restrictions expected in Norway

The further development of emission regulations is uncertain. When executing the programme, it is possible to investigate the effect of the following restrictions:

- Heavy duty vehicles of model year 1994 and later emit 25% less CO and 43% less NO_x than present standards.

- Light duty petrol driven vehicles of model year 1995 and later emit 0.40 g NO_x/km (previously: 0.62 g/km). These are the so called "California" regulations.

5.2.2 Low traffic roads

A situation often encountered by the user of RoadAir is wanting to calculate the total emission from road traffic in a certain area, e.g. a county which consists of both urban and rural areas. Traffic data are usually generated by use of a traffic model, and there is usually a lower limit to the traffic activity required for a road to be included in the defined network. In other cases, only a certain category of roads will be included. RoadAir gives the possibility of including emissions from roads not included in the network, if an estimate of the traffic activity on these roads is available. This may be given either in absolute numbers, or as a percent of the total

traffic activity on the defined road network. As for the defined road network, emission calculations are based on the average 24 hour velocity ("V").

5.2.3 Road intersections

The extra emissions due to acceleration, deceleration and idle in connection with road intersections may be calculated. At present, intersections with/without traffic lights, and round-abouts are included. Each road link may have an intersection in one, both or none of its end points. The emissions from road intersections are not accounted for in the basic emission module, and are therefore not included in the concentration calculations.

The emission calculations done for each link are in principle valid for the driving pattern in the middle part of each link (the parts of the link not affected by the intersections). The driving pattern close to the intersections is dominated by acceleration, deceleration and idle driving, giving additional emissions.

5.3 BACKGROUND POLLUTION

The pollution concentration near a given road equals the sum of the background concentration and the concentration due to emissions from the traffic in the road in question.

The background level may be due to local emissions from other sources (traffic, heating, industry), or due to long range transport. The latter is the case with ozone, which contributes to the level of NO_2. Near streets with high traffic activity, the ozone-based NO_2 formation is mainly described by the following reaction:

$$NO + O_3 \rightarrow NO_2 + O_2$$

The background level of CO and NO_2 will vary according to the degree of urbanization, as well as the dispersion conditions. The wind situation during the winter seasons is of particular importance. For towns and cities, the background pollution tends to decrease from the centre towards the outskirts.

For area type 1 (outskirts), the background pollution values are fixed in the programme: 1 mg CO/m^3, 5 µg NO_2/m^3. Table 9 below gives values suggested for area type 2 and 3. These values are proposed for Nordic towns. The background level of ozone is mainly due to long range transport. Based on our measurements, the value of 60 µg/m^3 is suggested to be used to account for the ozone contribution to NO_2 during high-pollution winter episodes.

Table 9: Recommended background pollution levels of CO, NO_2 and O_3 in Norway.
The values depend on area type and town population.

Population	CO (mg/m^3)		(NO_2 /µg/m^3)		O_3 (µg/m^3) (regionally)
	Central urban area OTY = 3	Intermediate area OTY = 2	Central urban area OTY = 3	Intermeidate area OTY = 2	
< 50 000	4	3	27	17	60
50-200 000	6	4	39	25	60
>200 000	11	7	68	43	60

5.4 EXPOSURE

This program module calculates the number of residents in buildings near the road exposed to various concentration levels of CO and NO_2. The calculations are done for the air outside the buildings where people live, based on the distance between the road and the building facades. In the building register, each building is allocated to the nearest street, and only the concentration contribution from that road is considered.

The building register includes data on number and residential units along each road link. The user must give the number of persons per residential unit, as an average for all units.

5.5 "NUISANCE"

The experience of nuisance due to air pollution along roads is due to the following factors:

- odour
- particles from the vehicle exhaust
- road dust.

The relative importance of these three factors to the nuisance experienced by individuals cannot easily be described. Odour from exhaust will mainly be due to volatile organic compounds, coming from both diesel and gasoline combustion. Exhaust particle emissions come mainly from diesel vehicles. The generation and resuspension of road dust is mainly due to the heavy duty vehicle fraction of the traffic flow.

It should be noted that the nuisance calculations are valid for the dry winter situation in countries where studded tyres are used extensively. The model is based on NO_2 concentrations as an indicator of nuisance. The reason for this is that both odour, exhaust particles and road dust particles is to a large extent due to heavy duty vehicles, which are also the main contributors to the NO_2 emissions. The quantitative connection between NO_2 concentrations and the number of people "severely bothered" is shown in Table 10 below. The numbers are based on results from the Traffic and Environment Project which was carried out in an area of Oslo with heavy traffic (Samferdsel, 1991).

Table 10: Relationship between NO_2 concentrations and fraction of the population "severely bothered" by air pollution from traffic. The numbers are valid for the urban situation of 1991 in Oslo.

Interval for maximum 1-hr average NO_2-concentration	Percentage of exposed people being severely bothered
<35	0
35- 75	15
75-125	30
125-175	40
175-225	50
225 275	65
275-325	75
>325	85

5.6 ROAD DUST DEPOSITION

Resuspension of road dust is the major cause of dust deposition near road. As for "nuisance", the road dust module is valid for the dry part of the winter season, in countries where studded tyres are in frequent use.

The following equation is used:

$$W = W_o \frac{AADT}{AADT_o} \cdot f_v \cdot f_{tt} \cdot f_d + W_b$$

- W - maximum dust deposition ($g/m^2 \cdot month$)
- W_b - dust deposition, bacground value
- AADT - average 24 hr traffic
- f_v - function of resuspension vs. vehicle driving velocity
- f_{tt} - function of resuspension vs. fraction of heavy duty traffic
- f_d - function of dust deposition vs. distance from the road side

the subscript "o" is used for the reference situation (see below).

Resuspension is assumed to be proportional to the square of the driving velocity ($f_v \alpha V^2$).

Resuspension is as a first estimate assumed to be proportional to the air resistance of the vehicles:

$$f_{tt} \alpha \quad 1 + \frac{k_2}{k_1} TA$$

k_1 and k_2 - air resistance factors of light and heavy duty vehicles respectively.
TA - fraction of heavy duty traffic

The ratio k_2/k_1 is set to 10.

f_d is based on a series of measurements of road dust deposition that have been carried out by NILU in Oslo.

Based on this, the following equation can be set up, describing the road dust deposition rate:

$$W = W_o \frac{AADT}{AADT_o} (\frac{V}{V_o})^2 \frac{1 + \frac{k_2}{k_1} TA}{1 + \frac{k_2}{k_1} TA_o} \cdot f_d + W_b$$

The reference traffic situation is described by $AADT_o$, V_o and TA_o. W_o is the road dust deposition in the reference situation.

RoadAir 2.0 uses the model described above for calculating maximum monthly road dust deposition (in $g/m^2 \cdot month$) along each road link. The deposition may be calculated at 5, 10 or 20 m from the curb for roads without facades. Along roads with facade coverage 1 or 2 (see paragraph 3.3.1) dust deposition is calculated 5 m from the road side. The classification of the dust deposition situation is shown in Table 11 below.

W_o is set to 175 $g/m^2 \cdot month$ at 5 m distance from the curb, for $AADT_o$ = 70 000 vehicles/24 hrs, V_o = 80 km/h and TA_o = 0.15. The distance function f_d is set to 1.0 at 5 m, 0.6 at 10 m and 0.35 at 20 m distance from the curb.

Table 11: Classification of road dust deposition (road dust class).

Dust deposition ($g/m^2 \cdot mth$)	<5	5-10	10-20	<20
Description of severity	Low dust deposition	Medium dust deposition	High dust deposition	Severe dust deposition
Road dust class	1	2	3	4

6 EXAMPLE OF PROGRAMME EXECUTION

The file Roadair2.exe can be installed on the hard disk, by copying it from a diskette:

```
C:\USER\AIR>copy b:Roadair2.exe
```

The files for road/traffic-data (e.g. link.txt) and buildings (e.g. build.txt) may be available on a diskette, placed in the b-drive.
The programme may also be executed from a diskette, but this trends to increase the execution time.

In the following, **bold** writing is used for messages given to the user and *italic* for instructions given by the user.

Programme execution is initiated by typing Roadair2

C:\USER\AIR>*Roadair2*

RoadAir 2.0 - a programme for calculation of air pollution parameters for road networks. ©NILU

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File containing road/traffic data:*b:link.text*
If the road/traffic-file is copied on to the directory C\USER\AIR, type only link.txt.

File for results: *b:result.txt*
If no directory is specified, the results will be written to the current directory.

Year of calculation:
This should be within the interval 1987-2009.

Do you want the calculations to be carried out for morning (1) or afternoon (2) rushhour?
The morning/afternoon-parameter affects the cold start fraction.

Input data being read!
If there are errors in the input data, you get the message:

Error in input data!
Further description of this message is given on the screen.

Assumption of "California"-emissions for light duty vehicles from 1996? (Y/N)
You only get this question if you have chosen a calculation year later than 1996. New emission regulation are described in paragraph 5.2.1.

Assumption of stricter emission regulations for heavy duty vehicles from 1994? (Y/N)
You only get this question if you have chosen a year of calculation later than 1994. See paragraph 5.2.1.

Emissions are being calculated!
Along roads with facades on one or both sides, road dust deposition is calculated 5 m from the curb.
Dust deposition along open roads may be calculated at 5, 10 or 20 meters from the road side. Choose the distance (5, 10 or 20 m):

Dust deposition includes all particle fractions, and is a major source to nuisance experienced by those living close to heavily trafficated roads. The dust deposition part of the model is valid for situations where studded tyres are used on dry roads, as is usual in Norway during part of the winter.

Should emissions from low traffic roads be included? (Y/N)
In most cases, only the roads with traffic above a certain limit will be included in the road/traffic file. If information on the size of the traffic activity on the remaining roads is available, then emission from these will be calculated, and added to the total emission.

If the answer to this question is yes, the following appears:

If emission on the low traffic roads are to be calculated, the traffic activities on these must be given as number of vehicle-km driven per 24 hours.
The number of vehicle-km driven on the defined road network is x km.

No. of vehicle-km/24 hours, central area:
No. of vehicle-km/24 hours, intermdiate area:
No. of vehicle-km/24 hours, outskirts:

You have now finished giving data for roads outside the defined road network.

At this point, the program will use a little time, before asking for the background concentrations of CO and NO_2 :

Background concentrations:
(CO-concentrations in mg/m^3:

CO - central area (0-15 mg/m^3):
CO - intermediate area (0-15 mg/m^3):
NO_2 - central area (0-150 µg/m^3):
NO_2 - intermediate area (0-150 µg/m^3):
Regional ozone concentration (0-200 µg/m^3):

The concept of background concentrations is described in chapter 5.3. The background concentration for rural areas/city outskirts lie fixed in the programme.

Distance from road side for concentration calculations of CO and NO_2:
The user must take care that the distance from the point of calculation to the centre of the road lies in the area 5-25 m.

Concentrations are being calculated!

Should exposure of the population to CO and NO_2 be calculated? (Y/N)
By "the population" is meant the people living in the houses adjacent to the defined roads, as defined in the building register. If the answer is yes:

Number of residents per housing unit?
This number is chosen uniformly for the whole building mass. If one wants to calculate the number of buildings rather than the number of people, the number of residents is set to one.

File containing data for buildings: *b:build.txt*

Exposure is being calculated!

Exposure calculations completed!

The printout of maximum concentrations for each road link may be arranged according to decreasing value. Would you like this to be done? (Y/N)

Should the values be arranged according to descending CO or NO2? (CO/NO2)
The sorting regards the last part of the printout, which gives information for each road link.

The links are being sorted!

Results stored on file: result.txt.

C:\USER\AIR>

You can now view the contents of result.txt in an editor, or make a printout.

7 REFERENCES

Traffic and the environment (1991) A trans-institutional research programme for road traffic, the environment and health in urban areas (NTNF). *Reprint from Samferdsel, n. 3 - 1991. Figure 19, p. 21.*

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ABSTRACT
RoadAir is a PC based model calculating air pollution parameters in connection with road traffic. These are: Emissions of CO, CO_2 and NO_x, concentrations of CO and NO_2, exposure to CO and NO_2, road dust deposition and "nuisance". Calculations are done for a whole network of roads. The programme is run interactively, and requires input files with data for traffic, roads, buildings, in specified format.

* Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C