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Traffic model system and emission calculations of the Helsinki Metropolitan Area Council

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General information about the area

The principal duties of the Helsinki Metropolitan Area Council (YTV) comprise transport system planning, regional public transport provision, waste management and air quality management for its four member municipalities (Helsinki, Espoo, Kauniainen and Vantaa). It also maintains regional databases and conducts studies on different issues affecting the region. Besides its member municipalities, YTV also serves a number of nearby municipalities on the basis of separate contracts.

The YTV area covers 764 square kilometres and contains a total population of approximately 980,400 (Dec. 31, 2004). With about 18.5 per cent of the country's population in just 0.2 per cent of its surface area, the YTV area's housing density is high by Finnish standards. The YTV area also has a high concentration of employment: approximately 573,600 jobs. Despite the intensity of land use, the region also has a great many recreational areas and green spaces.

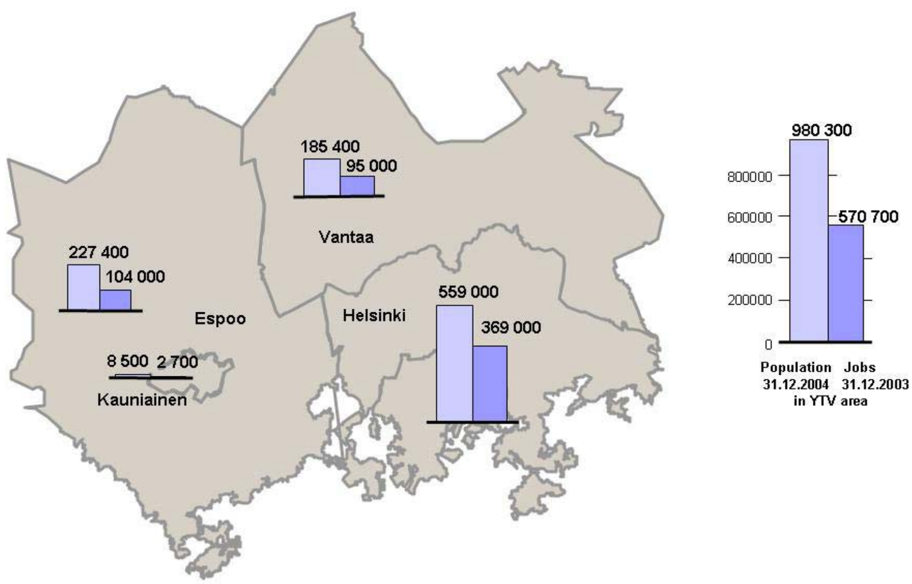

Figure 1. Population and number of jobs in the YTV area.

Around the YTV area, there are eight municipalities which together are called the surrounding areas. Helsinki region (Figure 2) is formed by the YTV area and the surrounding areas. YTV uses the term Metropolitan area - quite inconsistently - to describe an area contained within approximately a 100 kilometre radius from Helsinki. The entire Metropolitan area consists of 72 municipalities. Figure 3 shows the enlargement of the commuting area of Helsinki.

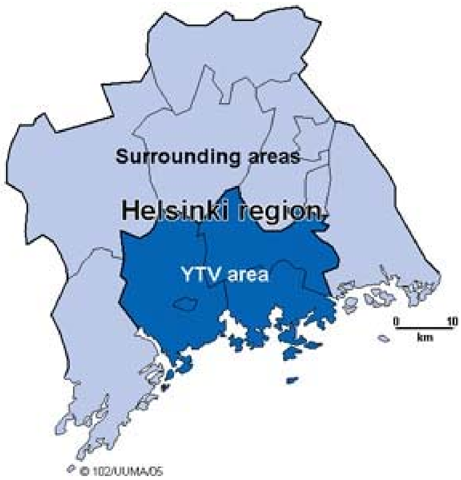

Figure 2. Helsinki region consists of four cities called the YTV area and eight municipalities in its surroundings.

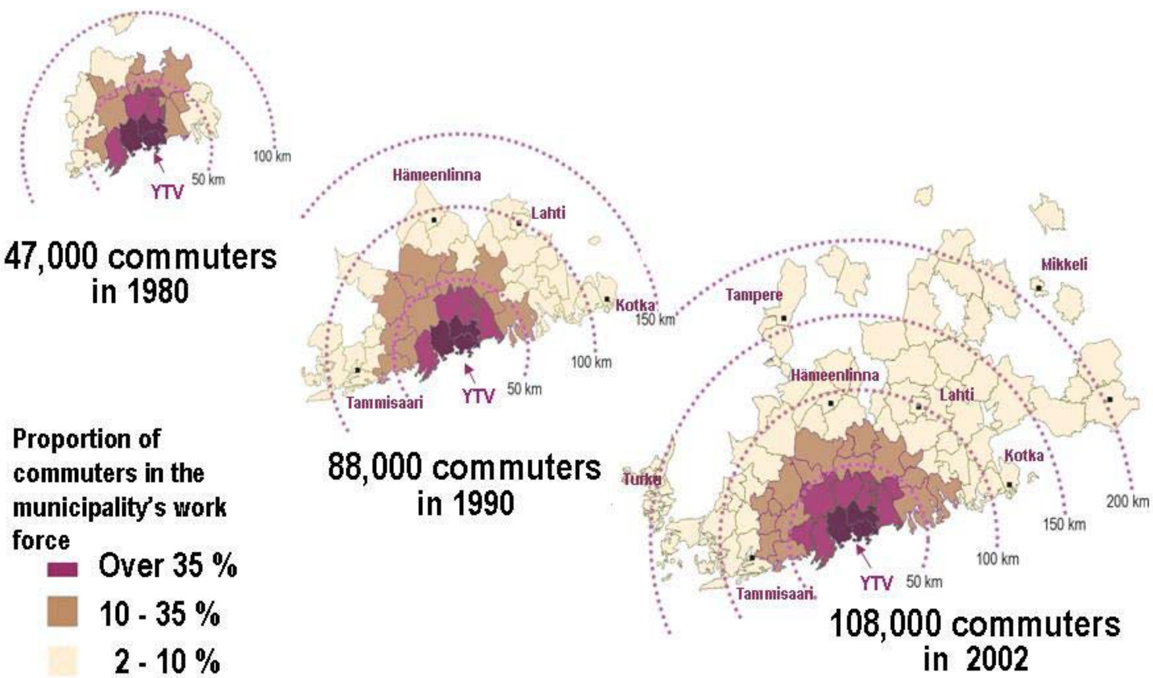

Figure 3. Commuting area of Helsinki.

The railways and main roads of the YTV area are presented in Figure 4. Freeways, arterials and main streets in the YTV area usually have two or three lanes to each direction.

Coastal railway line connects the area to Turku which is the former capital of Finland and port of departure for some of the ferry lines to Sweden, while the main railway line provides connections to the rest of Finland and St Petersburg, the former capital of Russia. The Vantaankoski railway line serves local passenger traffic only and metro lines connect the centre of Helsinki to the eastern suburbs. There are also boat and ferry connections to Stockholm and Tallinn, capitals of Sweden and Estonia respectively, from two passenger harbours in Helsinki centre.

Planned extensions of the network are in red, e.g. Ring Road III to the Vuosaari cargo harbour which is under construction and shall replace two present cargo harbours in Helsinki centre. A new railway line is supposed to connect Vantaankoski and the main railway line to the Helsinki-Vantaa international airport which is the busiest airport in Finland. A decision to expand the metro network to Southern Espoo was made in September 2006. Also a central tunnel under Helsinki CBD and an extension of Ring Road II between Turku arterial road and Tampere main road are supposed to be included in the transport system in 2030.

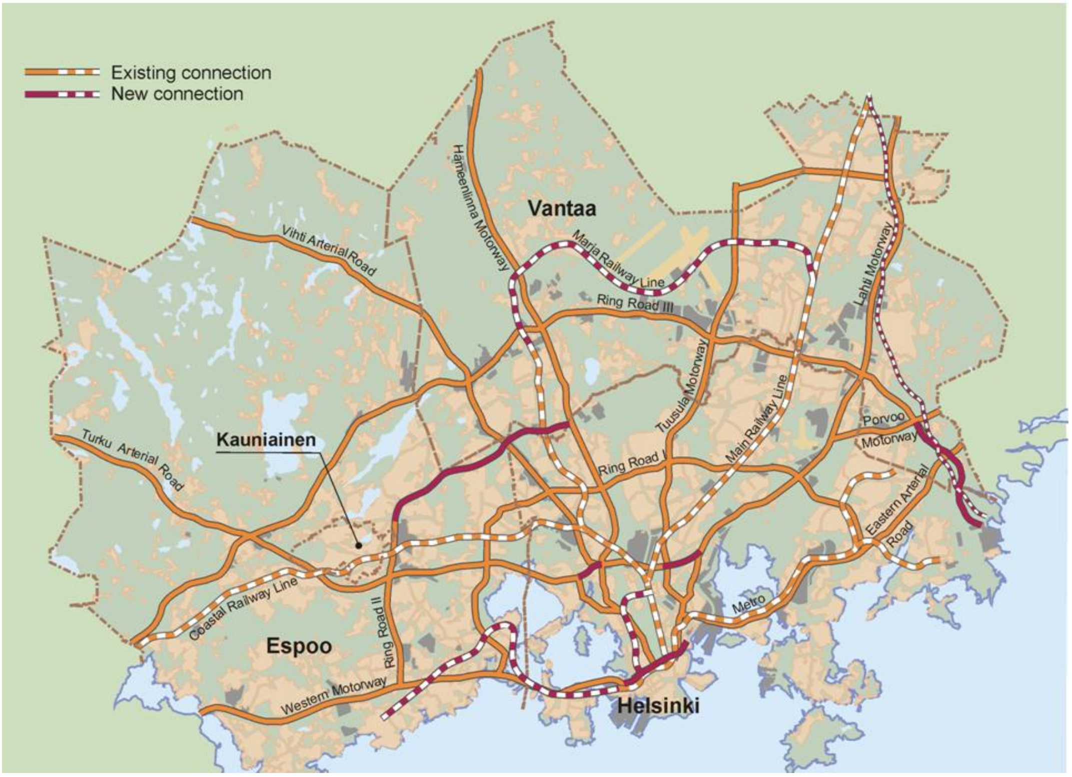

Figure 4 Target network in 2030.

Traffic model system

YTV Transport uses an Alpha Server computer using Tru64Unix operating system to run Emme/2. We are going to transfer our license to Linux environment.

The model system is coded in Emme/2 macros which contain Unix file handling commands. Some of the macros are written with SAS programs. Unix scripts are used e.g. for renaming output files.

The model system used for trips generated by inhabitants of the YTV area is a four-step model which consists of trip generation, destination choice, mode choice and route choice models. Trips are divided in four categories: home-based (work, school and other) and non-home-based.

Trip generation models are based on average trip production rates. Destination choice and mode choice models are logit models except mode choice model of school trips. There are three modes: car, public transit and walking+cycling. Also models of four or five modes are possible. In these models, walking and cycling can be separated or public transit can be divided in bus+tram and heavy rail. According to the definition used by YTV, the mode of a trip made by public transit is heavy rail if metro or train is used, otherwise its mode is bus+tram.

The formulas of logit model and logsum variable are below:

probability of alternative *i*

$$P_i = \frac{e^{V_i}}{\sum_{j=1}^{J} e^{V_j}}.$$

$$\text{logsum} = \ln\left(\sum_{j=1}^{J} e^{V_j}\right)$$

where

$V_i = \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_n x_{ni}$, where

V_i = benefit function of alternative i

β_j = coefficient of variable x_j (j = 1,2,…, n)

x_{jk} = value of variable x_j in alternative k.

The YTV area is divided into 129 zones. The input data used for the models includes e.g. the number of inhabitants, jobs and cars in each zone in addition to number of transfers, modal travel times and costs between each pair of zones. Some of the variables used in the models are shown in Table 1. A more detailed list of variables and corresponding coefficients can be found in Appendix 1.

The results are so called trip matrices or numbers of trips between each pair of zones using different modes (car, public transit or walking+cycling).

The structure of all models (except school trip models) is the same. In order to make several models possible the macros are made quite general which means e.g. that there are no constants in model formulas but scalar numbers. If some variable is not included in the model, its coefficient is zero.

Table 1. Scalars containing the coefficients.

model	variables	coefficients		
		home-based work trips	other home-based trips	non-home-based trips
destination	logsum	ms106	ms156	ms206
destination	scale factor	ms107	ms157	ms207
destination	ln(jobs)	ms108	ms158	ms208
mode	dummy, walk	ms110	ms160	ms210
mode	dummy, bus+tram	ms111	ms161	ms211
mode	dummy, car	ms112	ms162	ms212
mode	travel cost, heavy rail	ms115	ms165	ms215
mode	travel cost, bus+tram	ms116	ms166	ms216
mode	travel cost, car	ms117	ms167	ms217
mode	parking ratio	ms118	ms168	ms218
mode	parking cost	ms119	ms169	ms219

Corresponding models are used for trips generated by Helsinki-Vantaa airport (both passengers and employees).

When modifying the macros it is very useful to be systematic. E.g. the coefficient of logsum variable for work trip model is in scalar ms106 while the respective coefficients of logsum variables for other home based and non-home-based trips are in scalars ms156 and ms206 (see Table 1 or Appendix 1). Several advantages are achieved:

- One can modify the macro of one mode, copy it to the corresponding macros of other modes and substitute most occurrences of e.g. ms10 with ms15 or ms20.
- One can give the number of the first input matrix as a parameter of the macro and calculate the numbers of consecutive matrices. E.g. if the number of transfers is in matrix %2% (or the second parameter of the macro call), transit time can be in matrix r2=%2%+1**.**

Some kind of guiding or logical scalars, e.g. number of modes (3, 4 or 5) or version of mode choice model of school trips (96 or 2001) are used in the macros. Table 2 demonstrates the influence of certain scalars on text registers and titles of some matrices.

Table 2. Influence of the number of modes (ms149, ms199, ms249, ms299) on text registers and description fields of matrices (e.g. ”morning peak %t2% work trips”).

	number of modes (ms149, ms199, ms249, ms299)			
	3	4	-4	5
t1	walk+bicycle	walk+bicycle	walk	walk
t2	transit	bus+tram	transit	bus+tram
t3	car	car	car	car
t4	EI-PP	EI-PP	bicycle	bicycle
t5	EI-RAI	heavy rail	EI-RAI	heavy rail

Log of the run is saved to a standard Emme/2 reports file but the most important details (e.g. name of the scenario, starting date and time of the run, stopping criteria and assignment method used) are also saved to a smaller file. During the run, the name of the macro completed is displayed on the screen.

An example of an Emme/2 dialog needed to save a summary (in this case a sum of all values) of one forecasted matrix is on the right. Twenty-four similar scalars are needed for a summary report. Of course one could copy and paste this section 24 times and edit the parts which are underlined. A more convenient way, however, is to write a SAS program (a programming language can be used as well) and give the changing part as data cards. A demo program can be found in Appendix 2 and the Emme/2 macro generated by it in Appendix 3.

```
 1
 y
 ms311
 y
 wt24h
 home-based work trips
~?q=1
 y

 mf301



 y
 gn01,gn04

 o

 +
 +
~?b=1
 2
```

A list of scalars is output to an external file and a FORTRAN program is used to collect a summary of the main results from the scalar list (Appendix 4).

Before the auto assignment, the total number of vehicle trips between zones is calculated by adding the number of car trips made by people living outside the region as well as van and lorry trips, both calculated using simple models, to the car trips made by people living in the region. In these models used, the YTV area has been divided into 117 zones. In trip matrices, there are also 57 zones outside the YTV area.

Because the auto assignment is capacity restrained, there is a feedback to mode choice and destination choice in the system, i.e. the auto times calculated are used as input for the next iteration. Usually five iterations are made.

Network models

YTV has made auto network models. The most important intersections are the nodes of the model. The links are directional connections between the nodes and they have certain attributes, e.g. length, number of lanes and volume-delay function which gives the travel time on the link. When the auto network is loaded using a demand matrix (so called assignment), volumes and average speeds for each link are obtained. The assignment method is a capacity restrained equilibrium, i.e. at the equilibrium no one can improve their travel time by changing paths. In the regional auto network models used in the emission calculations, there are 284+57 zones, approximately 1,900 nodes and approximately 4,200 links. The auto networks used in the traffic model system are the same except that there are 129+57 zones in them.

Public transit system models consist of lines and a transit network. Each line has a name, a route (i.e. a chain of nodes) and average headway while e.g. transit length and average speed are link attributes. There are also connectors (i.e. walking links between zones and bus stops or stations) in addition to transfer links in the network model. Travel times and number of transfers between zones are obtained when the transit network is loaded using the transit demand matrix. Network models for the years 2000 and 2025 have been made.

Table 3. Statistics of transit networks.

	year	
	2000	2025
zones	597	597
bus lines	292	249
tram lines	10	12
heavy rail lines	11	14
bus links	4,800	5,300
tram links	300	380
heavy rail links	100	200

Estimation of models

YTV's Transport Department calculates traffic volumes and average speeds using traffic models, which have been estimated in the Laboratory of Transportation Engineering of the Helsinki University of Technology. The models are based on travel survey data from autumn 2000 including information about weekday trips made by approximately 8,700 inhabitants of the YTV area (i.e. cities of Helsinki, Espoo, Vantaa and Kauniainen). The total number of trips was 27,600, of which 26,700 inside the YTV area.

More than 50 model sets were estimated and tested. Most of the differences between the models were in the set of variables used. Also the effect of parameters on transit assignment and the model hierarchy (mode choice after destination choice or vice versa) were tested.

A traffic survey of the Helsinki-Vantaa airport area was made in autumn 2001. Survey data contains answers from 875 air passengers and 801 employees (flying and non-flying). This data was used for estimating models for trips generated by the Helsinki-Vantaa airport.

An origin-destination study made in autumn 1988 gave matrices for external trips and freight transport (van and lorry). External trips are car trips crossing the borders of the YTV area or made inside the YTV area by persons living outside it. Traffic flow matrices are updated on the basis of changes in land use according to a procedure similar to growth factor method. The models estimated in 1990 are used for forecasting these trips.

Forecasts and loading of networks

YTV's Transport System Plan PLJ 2002 supposes that there are 1,133,500 inhabitants, 662,400 jobs and approximately 456 cars per 1,000 inhabitants in the YTV area in 2025. The corresponding figures in the YTV area in 2000 are 928,950 inhabitants, 540,401 jobs and 348 cars per 1,000 inhabitants.

The trip matrices for the morning peak, evening peak and average daytime hours are forecasted using traffic models. There are 129 zones in the forecasted matrices so they must be divided into 284 zones in auto network and 597 zones in public transit network using proportion vectors based on numbers of inhabitants and jobs in the zones.

The dispersion modelling made by the Finnish Meteorological Institute requires link emissions for every hour over the year. The problem is solved by using regression models to calculate vehicle trip (car+van+lorry) matrices for ten weekday hours, seven Saturday hours and seven Sunday hours from those three hourly matrices. The regression models have been estimated using volume counts on four cordon lines.

The auto demand matrices constructed with regression models are used as input of auto assignments which produce hourly auto volumes and average speeds for each link.

There are only two sets of transit lines, i.e. morning peak and daytime lines in the transit system model. After transit assignment, transit volumes and average speeds on links are achieved.

Emission factors

Sulphur dioxide, carbon dioxide, carbon monoxide, nitrogen oxides, hydrocarbon and particle emissions are calculated using volumes and average speeds on the links. All emission factors are expressed as functions of average speed. Neither accelerations or decelerations, nor variations of speed are taken into account separately but they are all included in the average speed on the link. Examples of emission factors are in Figures 5–8.

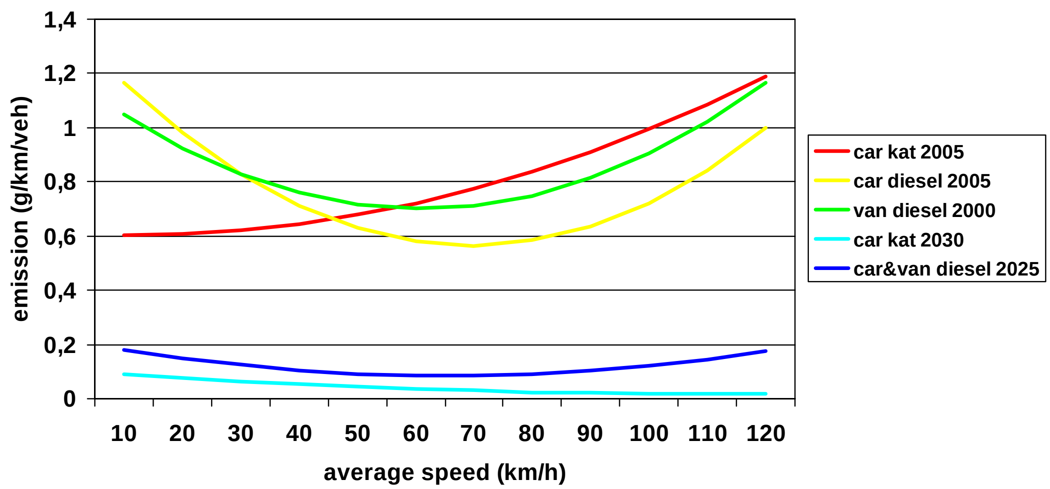

Figure 5. NO_x emissions of cars and vans.

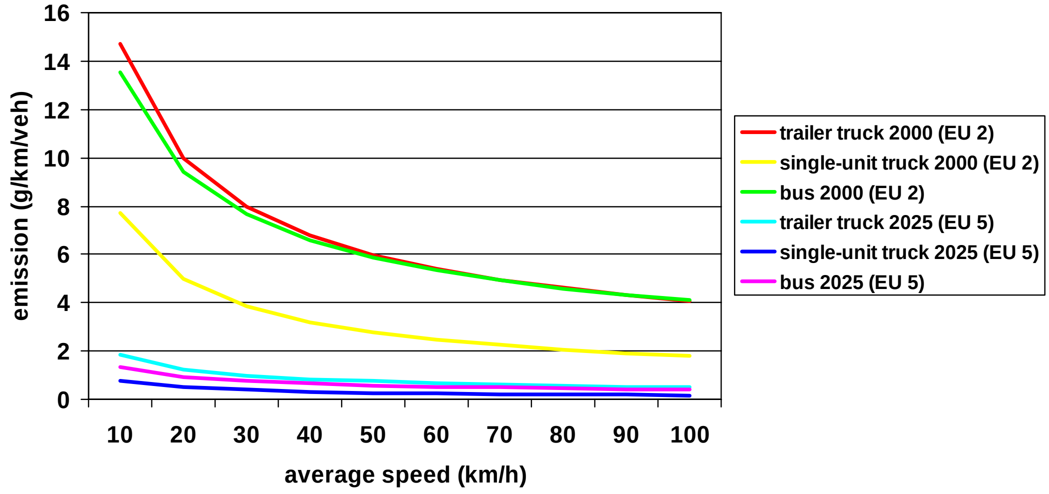

Figure 6. NO_x emissions of trucks and buses.

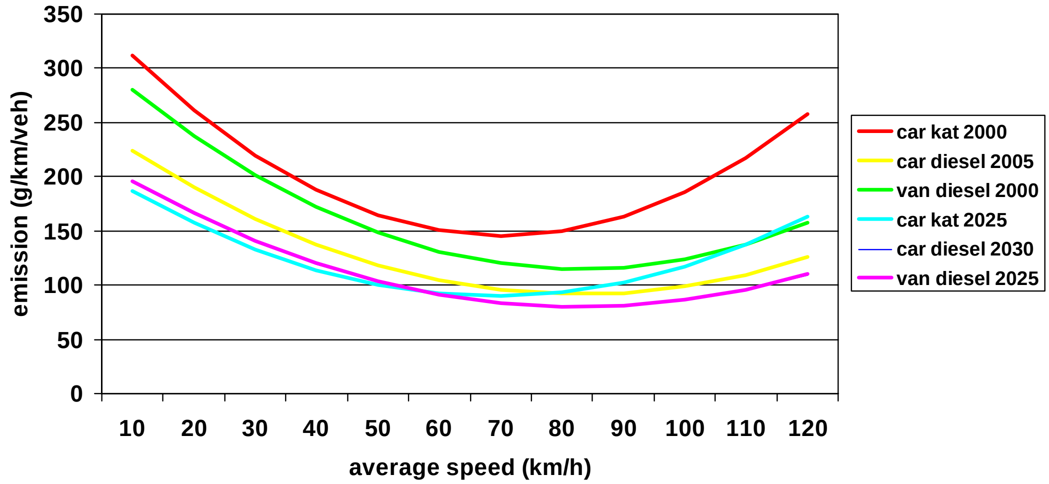

Figure 7. CO_2 emissions of cars and vans.

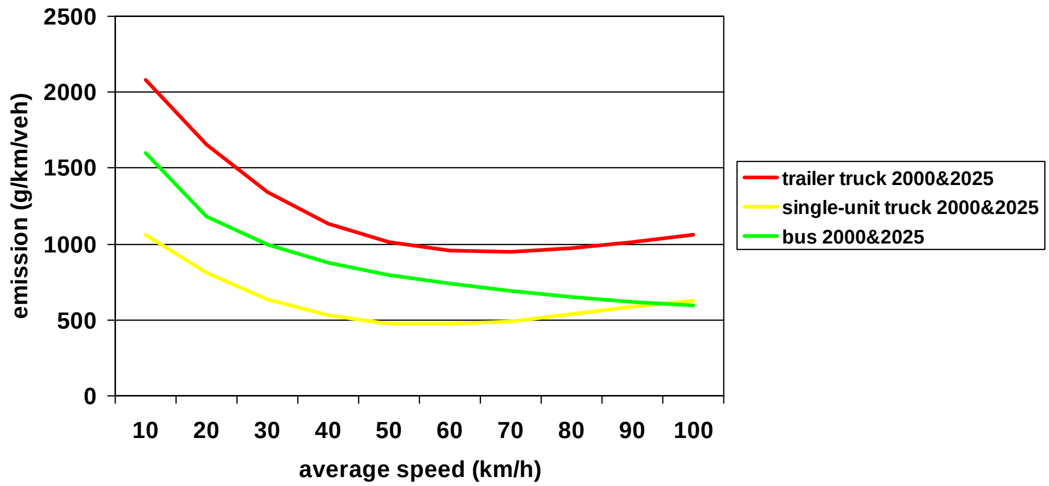

Figure 8. CO_2 emissions of trucks and buses.

There are emission factor functions for 14 different vehicle types depending e.g. on whether there is a catalytic converter in a car or a trailer attached to a lorry. There are separate emission factor functions for diesel cars and vans as well. The EU regulations are taken into account so that the emission factors for 2025 are smaller than those for the year 2000. In addition, emission factors of diesel and gas buses depend on the average speed. The emissions of the links are saved in extra attributes. Proportions of vehicle types are in Table 4. A more detailed table with names of the corresponding extra attributes is in Appendix 5.

Table 4. Proportion of vehicle types in emission calculations.

	year		percentage
	2000	2025	in scalar
cars and vans			
cars, non-kat	0	0	ms80
cars, kat-1995	**80** 4)	0	ms81
cars, kat-2020	-	**85** 5)	ms82
cars, diesel 1995	10	0	ms83
cars, diesel 2020	-	5	ms84
vans, diesel 1995	10	0	**ms69**
vans, diesel 2020	-	10	ms85
total	100	100	
trucks			
single-unit trucks EU 0-2	70	5	ms86
trailer combination trucks EU 0-2	30	2	ms87
single-unit trucks EU 4-5	-	65	ms88
trailer combination trucks EU 4-5	-	28	ms89
total	100	100	
buses			
LPG or CNG buses	6)	6)	
buses in Helsinki EU 0-2	100	0	ms81
regional buses EU 0-2	100	0	ms83
buses in Helsinki EU 4-5	-	100	ms82
regional buses EU 4-5	-	100	ms84

4) emission factors for average petrol car in 2000 (43 % non-kat, 52 % EU0-2, 5 % EU3, 0 % EU4-5)
5) emission factors for average petrol car in 2025 (0 % non-kat, 0 % EU0-2, 25 % EU3, 75 % EU4-5)
6) diesel bus volumes and gas bus volumes handled separately.

Emission calculations

The calculation system is coded in Emme/2 macros which contain Unix file handling commands. Unix scripts are used e.g. in dialog of FORTRAN run and in renaming output files.

Auto assignment has produced volumes and average speeds for each link for the above mentioned 10+7+7 or 24 hours. They are used when calculating the emissions. The average proportions of different vehicle types of total volumes are the same in the whole region. Emissions for other hours of the week (i.e. 14 weekday, 17 Saturday and 17 Sunday hours) are calculated from those 24 hours using copying or interpolation. Some examples of copying and interpolation of the emissions (from 10+7+7 hours to 14+17+17 hours) are shown in Table 5, while the thorough table is in Appendix 6.

Emissions from cold starts and emissions on lower level streets not included in the auto network model are based on the number of trips departing from each zone. However, they are not included in the dispersion calculations because they cannot be described as a point or a line source.

Table 5. Example of copying and interpolation of the emissions (from 10+7+7 hours to 14+17+17 hours).

hour	hour	weekday emission
4am- 5am	4- 5	EMIS_WD_23_5
5am- 6am	5- 6	EMIS_WD_23_5
6am- 7am	6- 7	(EMIS_WD_23_5 + EMIS_WD_7)/2.
7am- 8am	7- 8	EMIS_WD_7
8am- 9am	8- 9	EMIS_WD_8
9am-10am	9-10	EMIS_WD_9_13
10am-11am	10-11	EMIS_WD_9_13

Public transit emissions are calculated using assigned transit volumes and average speeds of each link in the morning peak hour and an average daytime hour. Regression models are used to get transit volumes and emissions for other hours on weekdays, Saturdays and Sundays.

The emissions caused by electricity production for tramways and heavy rail as well as emissions from vehicles in tunnel sections are included in total emissions but not in the dispersion calculations.

A diagram of the whole procedure used in emission calculations is in Figure 9.

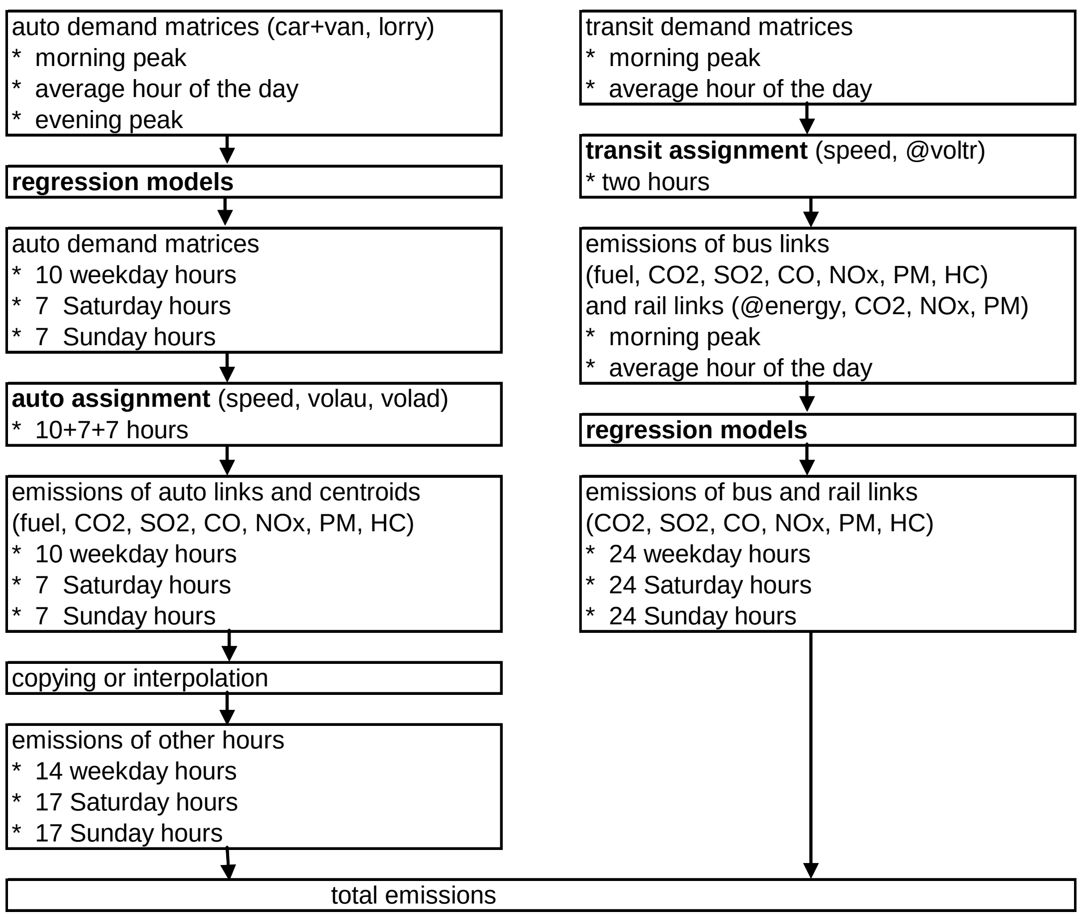

Figure 9. Emission calculation procedure.

Appendix 1. Variables, coefficients and corresponding matrices used in models.

model	variables	coefficients			corresponding matrices		
		home-based work trips	other home-based trips	non-home-based trips	morning peak hour	average hour of the day	evening peak hour
	model structure	ms100	ms150	ms200			
destination	logsum	ms106	ms156	ms206	mf75	mf155	mf195
destination	scale factor	ms107	ms157	ms207	md30	md31	md32
destination	ln(jobs)	ms108	ms158	ms208	ln(mo10')	ln(mo10')	ln(mo10')
destination	dummy of the zone	ms109	ms159	ms209	md27	md28	md29
mode	dummy, walk	ms110	ms160	ms210			
mode	dummy, bus+tram	ms111	ms161	ms211			
mode	dummy, car	ms112	ms162	ms212			
mode	dummy, bicycle	ms113	ms163	ms213			
mode	dummy, heavy rail	ms114	ms164	ms214			
mode	travel cost, heavy rail	ms115	ms165	ms215	mf25	mf26	mf26
mode	travel cost, bus+tram	ms116	ms166	ms216	mf25	mf26	mf26
mode	travel cost, car	ms117	ms167	ms217	ms02*mf31	ms03*mf33	ms04*mf35
mode	parking ratio	ms118	ms168	ms218	md24	md25	md26
mode	parking cost	ms119	ms169	ms219	md21	md22	md23
mode	nr of transfers, bus+tram	ms120	ms170	ms220	mf50	mf55	mf60
mode	travel time, bus+tram	ms121	ms171	ms221	mf51	mf56	mf61
mode	travel time, car	ms122	ms172	ms222	mf30	mf32	mf34
mode	nr of transfers, heavy rail	ms123	ms173	ms223	mf53	mf58	mf63
mode	travel time, heavy rail	ms124	ms174	ms224	mf54	mf59	mf64
mode	ln(distance), walk	ms125	ms175	ms225	mf10	mf10	mf10
mode	distance 0-5 km, walk	ms126	ms176	ms226	mf11	mf11	mf11
mode	distance 5-10 km, walk	ms127	ms177	ms227	mf12	mf12	mf12
mode	ln(distance), bicycle	ms130	ms180	ms230	mf10	mf10	mf10
mode	distance 0-5 km, bicycle	ms131	ms181	ms231	mf68	mf68	mf68
mode	distance 5-10 km, bicycle	ms132	ms182	ms232	mf69	mf69	mf69
mode	cars/household	ms135	ms185	ms235	mo18	mo18	mo18
mode	share of cars provided by the employer	ms136	ms186	ms236	mo21	mo21	mo21
mode	image of bus traffic	ms138	ms188	ms238	mf52	mf57	mf62
mode	image of heavy rail traffic	ms139	ms189	ms239	mf52	mf57	mf62
mode	logsum walk+bicycle	ms141	ms191	ms241			
mode	logsum transit	ms142	ms192	ms242			
mode	number of modes	ms149	ms199	ms249			

Appendix 2. Demo version of the SAS program which writes an Emme/2 macro.

```
title 'K:\Emme2\summary_matr_demo.SAS';

/*
********************************************
* Version 2 made: 18-SEP-2006 16:50 by Timo Elolähde
* Program: K:\Emme2\summary_matr_demo.SAS
* Task:    Write an Emme/2-macro, which calculates scalars for summary (demo)
********************************************
*/

libname  oma    'K:\Emme2';
filename outfi1 'K:\Emme2\summary_matr_demo1.mac';
filename outfi2 'K:\Emme2\summary_matr_demo2.mac';

options ls=130 ps=42 nocenter;

*** read values of matrix variables;

data matr;
length mxnro msnro $ 5 name $ 6 descr $ 40;
input mxnro $ 4-8 msnro $ 10-14 name $ 16-21 descr $ 23-62 ;
cards;
   mo09  ms301 nrinha total nr of inhabitants
   mf301 ms311 wt24h  home-based work trips 24h
   mf306 ms329 ms24ci car 24h CBD (incl. int) <--> other reg
   mf306 ms334 ms24ce car 24h CBD (excl. int) <--> other reg
         ms999        last line
   ;

*** write comments into the beginning of the macro;

data _null_;
set matr;
file outfi1;
pvm = date();

if _N_ = 1
then do;
   put "~# *** summary_matr_demo.mac ***" / "~#" /
       "~# calculate sum scalars of given matrices for the summary report" /
       "~# TE " pvm day2. "-" pvm monname3. "-" pvm year4. / "~#" /
              "~# parameter %1% = name of the log file" / "~#" /
       "~# Input:" /
       "~# mo09  = total nr of inhabitants" /
       "~# mf301 = home-based work trips" /
       "~# mf306 = car trips 24h whole region" /
       "~#" / "~# Output:";
end;
if (substr(msnro,3,3) ne '999') then put "~#" msnro $ 4-8 " = " descr $ 12-51 ;

*** write the calculation section of the macro;

data _null_;
set matr;
file outfi2;

if _N_ = 1
then do;
   put "~#" / "~p=2004" /
       "~?p=1" / "~! mv summary_matr_demo.txt  summary_matr_demo.old" /
       "~?p=2" / "~! rename summary_matr_demo.txt  summary_matr_demo.old" /
       " reports=%1%" /
       "~#" / " 3.21" / " 1" / " y" / " ms300" / " y" / " temp" /
       " temporary matrix" / "~?q=1" / " y" // " 0.0" /// "~?b=1" / " 2" / " q" /
```

```
       "~#" / "~#** calculate sums of vectors" / " 3.21" ;
end;

nro = substr(msnro,3,3);
** submatrix 1;
if (nro ne '999')
then do;
   put "~# *** matrix " _N_ " *** " ;
   put " 1" / " y" / msnro $ 2-6 / " y" / name $ 2-7 / descr $ 2-41 / "~?q=1" /
       " y" // mxnro $ 2-6 /// " y" ;
   if (substr(mxnro,1,2) = 'mo') then put " gn01,gn04" // " +"  ;
      else if nro in ('311')
         then put " gn01,gn04" // " o" // " +" / " +" ;
      else if nro in ('329')
         then put " gn01,gn04" // " gn01" // " +" / " +" ;
      else if nro in ('334')
         then put " gn02,gn04" // " gn01" // " +" / " +" ;
   put "~?b=1" / " 2" ;
end;

** submatrix 2;
if nro in ('329' '334')
then do;
   put "~# second submatrix";
   put " 1" / " y" / " ms300" / " n" / mxnro $ 2-6 /// " y" ;
   if nro in ('329')
         then put " gn01" // " gn02,gn04" // " +" / " +" ;
      else if nro in ('334')
         then put " gn01" // " gn02,gn04" // " +" / " +" ;
   put "~?b=1" / " 2" / "~#" ;
   put "~# combination of submatrices";
   put " 1" / " y" / msnro $ 2-6  / " n" / msnro $ 2-6 " + ms300" /// "~?b=1" / " 2"
/ "~#" ;
end;
else if (nro ne '999') then put "~# only one submatrix";

*** write the end of the macro;

if nro = '999'
then do;
   put " q" / "~#** output the list of scalars" /
       " reports=summary_matr_demo.txt" /
       " 3.14" / " 2" / " ms" / "~?b=1" / " 2" / " q" /
       " reports=%1%" /
       "~/ *** summary_matr_demo.mac ***" ;
end;

run;
```

Appendix 3. Emme/2 macro made by the SAS program in Appendix 2.

```
~# *** summary_matr_demo.mac ***
~#
~# calculate sum scalars of given matrices for the summary
report
~# TE 18-Sep-2006
~#
~# parameter %1% = name of the log file
~#
~# Input:
~# mo09  = total nr of inhabitants
~# mf301 = home-based work trips
~# mf306 = car trips 24h whole region
~#
~# Output:
~# ms301 = total nr of inhabitants
~# ms311 = home-based work trips 24h
~# ms329 = car 24h CBD (incl. int) <--> other reg
~# ms334 = car 24h CBD (excl. int) <--> other reg
~#
~p=2004
~?p=1
~! mv summary_matr_demo.txt  summary_matr_demo.old
~?p=2
~! rename summary_matr_demo.txt  summary_matr_demo.old
 reports=%1%
~#
 3.21
 1
 y
 ms300
 y
 temp
 temporary matrix
~?q=1
 y

 0.0


~?b=1
 2
 q
```

```
~#
~#** calculate sums of vectors
 3.21
~# *** matrix 1  ***
 1
 y
 ms301
 y
 nrinha
 total nr of inhabitants
~?q=1
 y

 mo09


 y
 gn01,gn04

 +
~?b=1
 2
~# only one submatrix
~# *** matrix 2  ***
 1
 y
 ms311
 y
 wt24h
 home-based work trips 24h
~?q=1
 y

 mf301


 y
 gn01,gn04

 o

 +
 +
~?b=1
```

```
 2
~# only one submatrix
~# *** matrix 3  ***
 1
 y
 ms329
 y
 ms24ci
 car 24h CBD (incl. int) <--> other reg
~?q=1
 y

 mf306


 y
 gn01,gn04

 gn01

 +
 +
~?b=1
 2
~# second submatrix
 1
 y
 ms300
 n
 mf306


 y
 gn01

 gn02,gn04

 +
 +
~?b=1
 2
~#
~# combination of submatrices
 1
 y
 ms329
 n
 ms329 + ms300


~?b=1
 2
~#
~# *** matrix 4  ***
 1
 y
 ms334
 y
 ms24ce
 car 24h CBD (excl. int) <--> other reg
~?q=1
 y

 mf306


 y
 gn02,gn04

 gn01

 +
 +
~?b=1
 2
~# second submatrix
 1
 y
 ms300
 n
 mf306


 y
 gn01

 gn02,gn04
```

```
 +
 +
~?b=1
 2
~#
~# combination of submatrices
 1
 y
 ms334
 n
 ms334 + ms300


~?b=1
 2
~#
 q
~#** output the list of scalars
 reports=summary_matr_demo.txt
 3.14
 2
 ms
~?b=1
 2
 q
 reports=%1%
~/ *** summary_matr_demo.mac ***
```

Appendix 4. Example of a summary report and comparison of two forecasts.

```
12.7.2005 11:40
 Scenario SKEN 1 from file summary_2000.txt
     5./ 5. iterations, max difference in modal split (%-unit) 0.00928/0.00000
    factor in airport model 1.150
 Scenario SKEN 2 from file summary_2025.txt
     5./ 5. iterations, max difference in modal split (%-unit) 0.08096/0.00000
    factor in airport model 1.150

                   SKEN 1      SKEN 2  change (%) change (abs)
 inhabit (total)   928950.    1133500.    22.0   204550.
 inhabit (age>7)   850210.    1063211.    25.1   213001.
 nr of jobs        540401.     662400.    22.6   121999.
 car ownership        348.        456.    31.1      108.
 nr of cars        323303.     517202.    60.0   193898.

                   SKEN 1      SKEN 2  change (%) change (abs)
 home-based work   688040.     800754.    16.4   112714.
 home-based school 197023.     219418.    11.4    22395.
 home-based other 1515510.    1925106.    27.0   409596.
 non-home-based    511243.     674475.    31.9   163231.
 total            2911816.    3619752.    24.3   707936.

                   SKEN 1      SKEN 2  change (%) change (abs)
   walk            879697.     996736.    13.3   117039.
   bicycle             0.          0.     0.0        0.
 sum of non-motor  879697.     996736.    13.3   117039.
   bus+tram        800837.     994560.    24.2   193723.
   heavy rail          0.          0.     0.0        0.
 sum of transit    800837.     994560.    24.2   193723.
 car              1231282.    1628456.    32.3   397174.

 total         2911816.    3619752.    24.3   707937.

                trip/inhabitant     trips/(inhab. age>7)
                SKEN 1    SKEN 2    SKEN 1    SKEN 2
   walk          0.95      0.88      1.03      0.94
   bicycle       0.00      0.00      0.00      0.00
 sum of non-moto 0.95      0.88      1.03      0.94
   bus+tram      0.86      0.88      0.94      0.94
   heavy rail    0.00      0.00      0.00      0.00
 sum of transit  0.86      0.88      0.94      0.94
 car             1.33      1.44      1.45      1.53

 total           3.13      3.19      3.42      3.40

 modal split day (24h) whole region
  SKEN 1 wb/tra/car  tra-%      SKEN 2 wb/tra/car  tra-%     trips
   30. / 28. / 42. // 39.4 %    28. / 27. / 45. // 37.9 %
  879697. / 800837. /1231282.   996736. / 994560. /1628456.   24.3 %

 modal split day (24h) inside centre and centre <--> other region
  SKEN 1 wb/tra/car  tra-%      SKEN 2 wb/tra/car  tra-%     trips
   29. / 39. / 32. // 54.5 %    28. / 40. / 32. // 55.3 %
  328624. / 440768. / 367565.   360862. / 506265. / 408512.   12.2 %

 modal split day (24h) centre <--> other region (incl inside centre)
  SKEN 1 wb/tra/car  tra-%      SKEN 2 wb/tra/car  tra-%     trips
    6. / 50. / 44. // 52.8 %     5. / 50. / 44. // 53.2 %
   38943. / 325636. / 290960.    40091. / 370030. / 325839.   12.3 %

 modal split morning peak whole region
  SKEN 1 wb/tra/car  tra-%      SKEN 2 wb/tra/car  tra-%     trips
   32. / 33. / 35. // 48.9 %    30. / 32. / 37. // 46.5 %
   98922. / 101714. / 106149.   111102. / 119561. / 137335.   20.0 %
```

```
modal split morning peak inside centre and centre <--> other region
 SKEN 1 wb/tra/car  tra-%      SKEN 2 wb/tra/car  tra-%     trips
  26. / 46. / 28. // 62.1 %    26. / 47. / 28. // 62.7 %
  26732. /  48427. /  29603.    29390. /  53559. /  31876.    9.6 %
```

```
modal split morning peak to centre (excl inside centre)
 SKEN 1 wb/tra/car  tra-%      SKEN 2 wb/tra/car  tra-%     trips
   6. / 59. / 35. // 63.0 %     6. / 60. / 34. // 63.9 %
   3137. /  31208. /  18351.     2970. /  32557. /  18399.    2.3 %
```

hourly vehicle kilometres and hours, average speeds

	morning peak			average hour of day			evening peak		
	SKEN1	SKEN2	change	SKEN1	SKEN2	change	SKEN1	SKEN2	change
1000 veh_km									
whole region	1308.	1913.	46.2	795.	1162.	46.2	1353.	1972.	45.8
Hki centre	146.	179.	22.5	100.	123.	23.4	176.	211.	19.9
Hki suburb	415.	522.	25.9	260.	331.	27.3	427.	542.	26.8
Espoo+Kaun	396.	621.	56.8	230.	363.	57.8	399.	625.	56.8
Vantaa	352.	591.	68.0	205.	345.	67.9	351.	595.	69.4

1000 veh_h									
whole region	31.6	47.7	51.1	16.8	24.1	42.9	33.4	50.4	51.0
Hki centre	5.1	6.2	21.1	3.1	3.7	18.7	6.4	7.8	22.5
Hki suburb	9.8	12.9	32.4	5.4	6.8	25.7	10.1	13.8	35.7
Espoo+Kaun	9.0	15.7	75.1	4.6	7.4	61.2	9.1	16.0	74.8
Vantaa	7.7	12.8	66.7	3.7	6.1	65.5	7.7	12.9	66.5

aver speed km/h									
whole region	41.5	40.1	-3.2	47.2	48.3	2.3	40.5	39.1	-3.4
Hki centre	28.5	28.8	1.1	32.3	33.6	3.9	27.5	26.9	-2.1
Hki suburb	42.4	40.4	-4.9	47.8	48.5	1.3	42.2	39.4	-6.6
Espoo+Kaun	44.1	39.5	-10.4	49.9	48.8	-2.1	43.6	39.1	-10.3
Vantaa	45.7	46.1	0.8	55.4	56.2	1.5	45.4	46.2	1.8

Appendix 5. Proportions of vehicle types and attributes used in emission calculations.

vehicle type	year		matrices	names of attributes						
	2000	2025	in scalar	CO	HC	NOx	particles	CO2	SO2	fuel
cars and vans										
cars, non-kat	0	0	ms80	@cohae	@hchae	@nohae	@pmhae	**@c2ha1**	**@soha1**	**@kuha1**
cars, kat-1995	**80** 4)	0	ms81	@coha1	@hcha1	@noha1	@pmha1	@c2ha1	@soha1	@kuha1
cars, kat-2020	-	**85** 5)	ms82	@coha2	@hcha2	@noha2	**@pmha1**	@c2ha2	@soha2	@kuha2
cars, diesel 1995	10	0	ms83	@codh1	@hcdh1	@nodh1	@pmdh1	@c2dh1	@sodh1	@kudh1
cars, diesel 2020	-	5	ms84	@codh2	@hcdh2	@nodh2	@pmdh2	@c2dh2	@sodh2	@kudh2
vans, diesel 1995	10	0	**ms69**	@codp1	@hcdp1	@nodp1	@pmdp1	@c2dp1	@sodp1	@kudp1
vans, diesel 2020	-	10	ms85	@codp2	@hcdp2	@nodp2	@pmdp2	@c2dp2	@sodp2	@kudp2
total	100	100								
trucks										
single-unit trucks EU 0-2	70	5	ms86	@coki0	@hcki0	@noki0	@pmki0	**@c2ki1**	**@soki1**	**@kuki1**
trailer combination trucks EU 0-2	30	2	ms87	@cokp0	@hckp0	@nokp0	@pmkp0	**@c2kp1**	**@sokp1**	**@kukp1**
single-unit trucks EU 4-5	-	65	ms88	@coki4	@hcki4	@noki4	@pmki4	**@c2ki2**	**@soki2**	**@kuki2**
trailer combination trucks EU 4-5	-	28	ms89	@cokp4	@hckp4	@nokp4	@pmkp4	**@c2kp2**	**@sokp2**	**@kukp2**
total	100	100								
totals of cars, vans and trucks				@coyht	@hcyht	@noyht	@pmyht	@c2yht	@soyht	
totals of trucks only				@coyh2	@hcyh2	@noyh2	@pmyh2	@c2yh2	@soyh2	
buses (separate transit network)										
LPG or CNG buses	6)	6)		@cobg	@hcbg	@nobg	@pmbg	**@c2bg**	**@sobg**	**@kubg**
buses in Helsinki EU 0-2	100	0	ms81	@cobh0	@hcbh0	@nobh0	@pmbh0	**@c2bh1**	**@sobh1**	**@kubh1**
regional buses EU 0-2	100	0	ms83	@cobs0	@hcbs0	@nobs0	@pmbs0	**@c2bs1**	**@sobs1**	**@kubs1**
buses in Helsinki EU 4-5	-	100	ms82	@cobh4	@hcbh4	@nobh4	@pmbh4	**@c2bh2**	**@sobh2**	**@kubh2**
regional buses EU 4-5	-	100	ms84	@cobs4	@hcbs4	@nobs4	@pmbs4	**@c2bs2**	**@sobs2**	**@kubs2**
totals of buses				@cobus	@hcbus	@nobus	@pmbus	@c2bus	@sobus	

4) emission factors for average petrol car in 2000 (43 % non-kat, 52 % EU0-2, 5 % EU3, 0 % EU4-5)
5) emission factors for average petrol car in 2025 (0 % non-kat, 0 % EU0-2, 25 % EU3, 75 % EU4-5)
6) diesel bus volumes and gas bus volumes handled separately.

Appendix 6. Interpolation and copying of emissions.

hour	hour	weekday emission	Saturday emission	Sunday emission
12am- 1am	0- 1	EMIS_WD_23_5	EMIS_SAT_23_6	EMIS_SUN_23_6
1am- 2am	1- 2	EMIS_WD_23_5	EMIS_SAT_23_6	EMIS_SUN_23_6
2am- 3am	2- 3	EMIS_WD_23_5	EMIS_SAT_23_6	EMIS_SUN_23_6
3am- 4am	3- 4	EMIS_WD_23_5	EMIS_SAT_23_6	EMIS_SUN_23_6
4am- 5am	4- 5	EMIS_WD_23_5	EMIS_SAT_23_6	EMIS_SUN_23_6
5am- 6am	5- 6	EMIS_WD_23_5	EMIS_SAT_23_6	EMIS_SUN_23_6
6am- 7am	6- 7	(EMIS_WD_23_5 + EMIS_WD_7)/2.	EMIS_SAT_23_6	EMIS_SUN_23_6
7am- 8am	7- 8	EMIS_WD_7	(EMIS_SAT_23_6 + EMIS_SAT_8)/2.	EMIS_SUN_7
8am- 9am	8- 9	EMIS_WD_8	EMIS_SAT_8	(EMIS_SUN_7 + EMIS_SUN_9)/2.
9am-10am	9-10	EMIS_WD_9_13	(EMIS_SAT_8 + EMIS_SAT_10)/2.	EMIS_SUN_9
10am-11am	10-11	EMIS_WD_9_13	EMIS_SAT_10	(EMIS_SUN_9 + EMIS_SUN_11)/2.
11am-12pm	11-12	EMIS_WD_9_13	(EMIS_SAT_10 + EMIS_SAT_12_15)/2.	EMIS_SUN_11
12pm-1pm	12-13	EMIS_WD_9_13	EMIS_SAT_12_15	(EMIS_SUN_11 + EMIS_SUN_13_16)/2.
1pm- 2pm	13-14	EMIS_WD_9_13	EMIS_SAT_12_15	EMIS_SUN_13_16
2pm- 3pm	14-15	EMIS_WD_14	EMIS_SAT_12_15	EMIS_SUN_13_16
3pm- 4pm	15-16	EMIS_WD_15	EMIS_SAT_12_15	EMIS_SUN_13_16
4pm- 5pm	16-17	EMIS_WD_16	(EMIS_SAT_12_15 + EMIS_SAT_17)/2.	EMIS_SUN_13_16
5pm- 6pm	17-18	EMIS_WD_17	EMIS_SAT_17	(EMIS_SUN_13_16 + EMIS_SUN_18)/2.
6pm- 7pm	18-19	(EMIS_WD_17 + EMIS_WD_19)/2.	(EMIS_SAT_17 + EMIS_SAT_19)/2.	EMIS_SUN_18
7pm- 8pm	19-20	EMIS_WD_19	EMIS_SAT_19	(EMIS_SUN_18 + EMIS_SUN_20)/2.
8pm- 9pm	20-21	(EMIS_WD_19 + EMIS_WD_21)/2.	(EMIS_SAT_19 + EMIS_SAT_21)/2.	EMIS_SUN_20
9pm-10pm	21-22	EMIS_WD_21	EMIS_SAT_21	(EMIS_SUN_20 + EMIS_23_6)/2.
10pm-11pm	22-23	(EMIS_WD_21 + EMIS_WD_23_5)/2.	(EMIS_SAT_21 + EMIS_SAT_23_6)/2.	EMIS_SUN_23_6
11pm-12am	23-24	EMIS_WD_23_5	EMIS_SAT_23_6	EMIS_SUN_23_6