REALITY
Road Emission Activity-Link based InvenTorY

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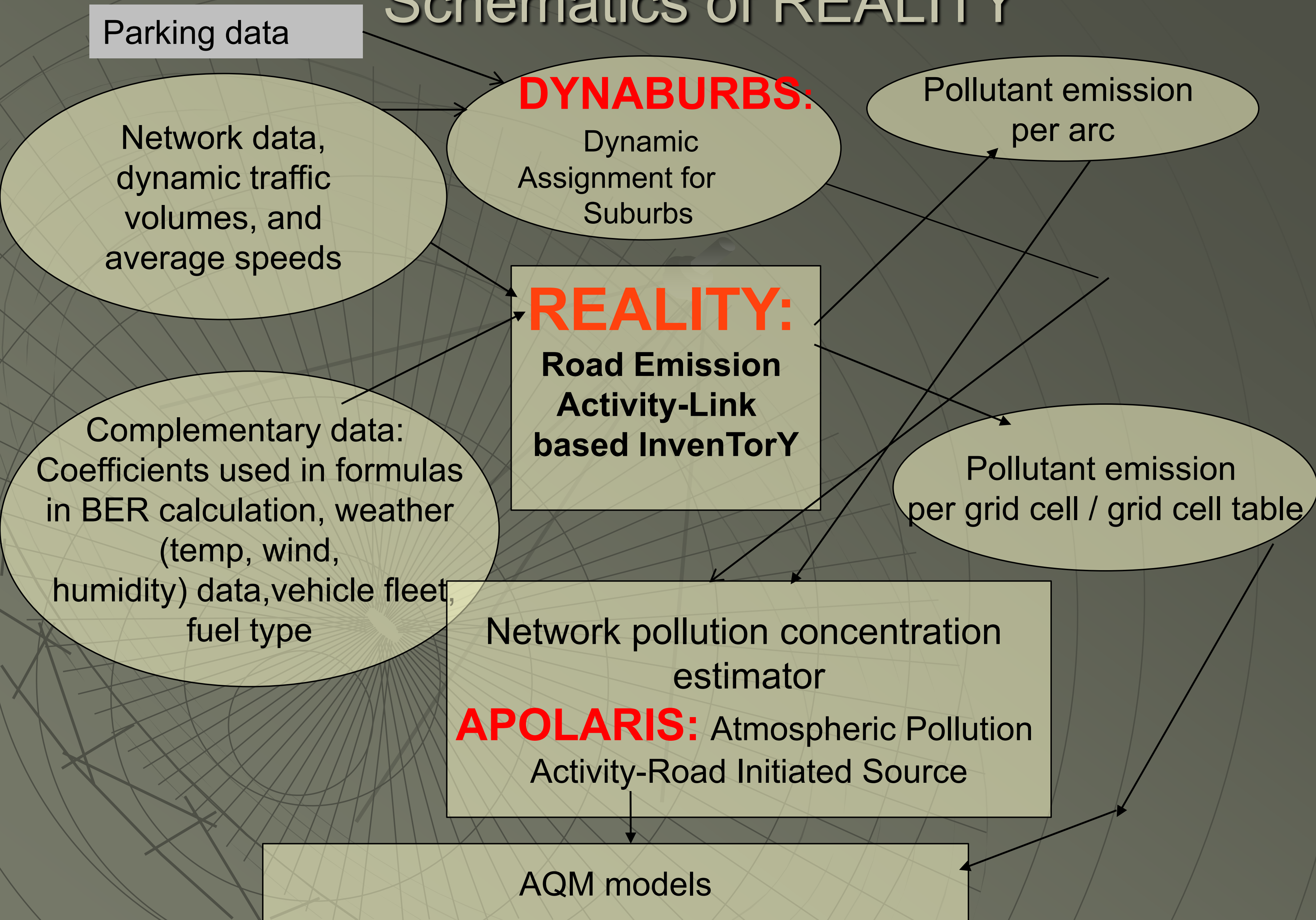
Schematics of REALITY



Introducing REALITY

(sponsored by Institut Carnot Vitres)

REALITY is a dynamic model of emission calculation of pollutants that result from traffic on a road network. Calculation can be made on precise locations (roads) or for the entire network (divided into grid cells). REALITY calculates hot emissions (vehicles running on hot engines).

- dynamic : with respect to time
  1. all day (24 hours)
  2. Per hour
  3. By fraction of an hour
  4. For each instant of time
- dynamic : with respect to traffic volume and speed
  1. traffic volumes on each road (link) of a network change as a function of time
  2. average speed on each link varies by time of day

Introducing REALITY

- dynamic : with respect to basic emission rates (BER)

  1. emission rates are calculated as non-linear functions of average speeds on each link of the network and thus change as speeds change.
  2. Basic emission rates are calculated for each arc of the network

- dynamic with respect to location:

  - Precise locations:

    1. Per arc or per segment of arc
    2. Per grid cell (a collection of arcs)
    3. At a network level: a collection of arcs, or (a collection of grid cells)

Dynamic Traffic Assignment and REALITY

Network equilibrium dynamic traffic assignment: (New feature of the model REALITY)

-given a variable matrix of origin – destination travel demand, traffic volume is distributed among the links in a network in a way that the costs of taking these roads are equal in the network (the Wardrop principal). When due to change in activity level or activity type origin - destination matrices vary in time, traffic volumes and average speeds which are distributed vary respectively.

- link average speeds are calculated using the fundamental diagram, which gives the following relationship between traffic flow , density, and speed:

$$q(t) = k(t)v(t)$$

$$v(t) = Q\big(k(t)\big)$$

q(t) = traffic flow during time interval (t)

k = density during time interval (t)

v =average speed during time interval (t)

Calculation of Basic Emission Rates (BER): REALITY

- BERs are calculated as functions of average speed, itself calculated by a network equilibrium dynamic assignment model
  - *BER = f(v(p,k,m,t,i))*

An example of a speed equation

$$f(v(p,k,m,t,i)) = a * v(p,k,m,t,i) + b * v(p,k,m,t,i)^2 + c$$

- BER = basic emission rate (gr/km) per pollutant (p), for car class (k), and fuel type (m) during time interval (t) and per link (i).
- a,b,c are coefficients from COPERT adjusted for use in REALITY
- Equations follow COPERT guidelines
- COPERT is a European equivalent of MOBILE6
- *v(p,k,m,t,i)* = average speed per pollutant (p), for car class (k), and fuel type (m) during time interval (t) and per link (i).

Calculating link pollutant emissions in REALITY

- Pollutant emissions are calculated on each link (i), for car class (k), and fuel type (m), during interval (t).
- Pollutant emissions per link :

$$E(p,i,k,m,t) = y(p,i,k,m,t) * v(p,i,k,m,t) * l(i)$$

E(p,i,k,m,t) = is the emission of pollutant (p), on link (i), for car class (k), and fuel type (m) during time interval (t).

- *y*(p,i,k,m,t) = is the emission factor for pollutant (p), link (i), car class (k), fuel type (m), and time interval (t).
- *v*(p,i,k,m,t) = is the volume of car class (k) differentiated by fuel type (m) on link (I) and time interval (t).
- *l*(i) = length of link (i) traveled by vehicles

Calculation of pollutant emissions by grid cell in REALITY

Total emission is calculated as the sum of link emissions multiplied by the fraction of each link in each cell.

- Emissions per grid cell :

$$\Phi_t^{p,k,j,m} = \sum E_t^{p,k,i,m} \times \alpha^{ij}$$

$\Phi_t^{p,j,k,m}$ = is the total emission of pollutant (p) for car class (k) with fuel intake of type (m) during interval (t) in grid cell (j); j = 1,.....,M

$E_t^{p,i,k,m}$ = is link emission of pollutant (p), for car class (k = 1,....,L), with fuel intake of type (m)

$\alpha^{i,j}$ = is the fraction of link (i) in cell (j)

car class includes: type and age

Application of REALITY

- Case study: Ile de France (Paris metropolitan area)

-hot pollutant emission calculation for urban and non-urban (highways, expressways) on the Ile de France network

- hot pollutant emission calculation on grid level, where each grid contains a collection of arcs of the network

- graphical representation of the model application for CO, and NOx

Île de France (Paris metropolitan) network

- Network size : 36583 arcs

- Network equilibrium dynamic assignment output: link flows , and average speeds per time interval

Time interval: hourly for 24 hours

- Pollutant emissions are calculated for each arc of the network of l'Ile-de-France by grid cell: grid cells of size 0.5 degrees longitude and latitude: total number of grid cells: (43 x 24 grid cells)

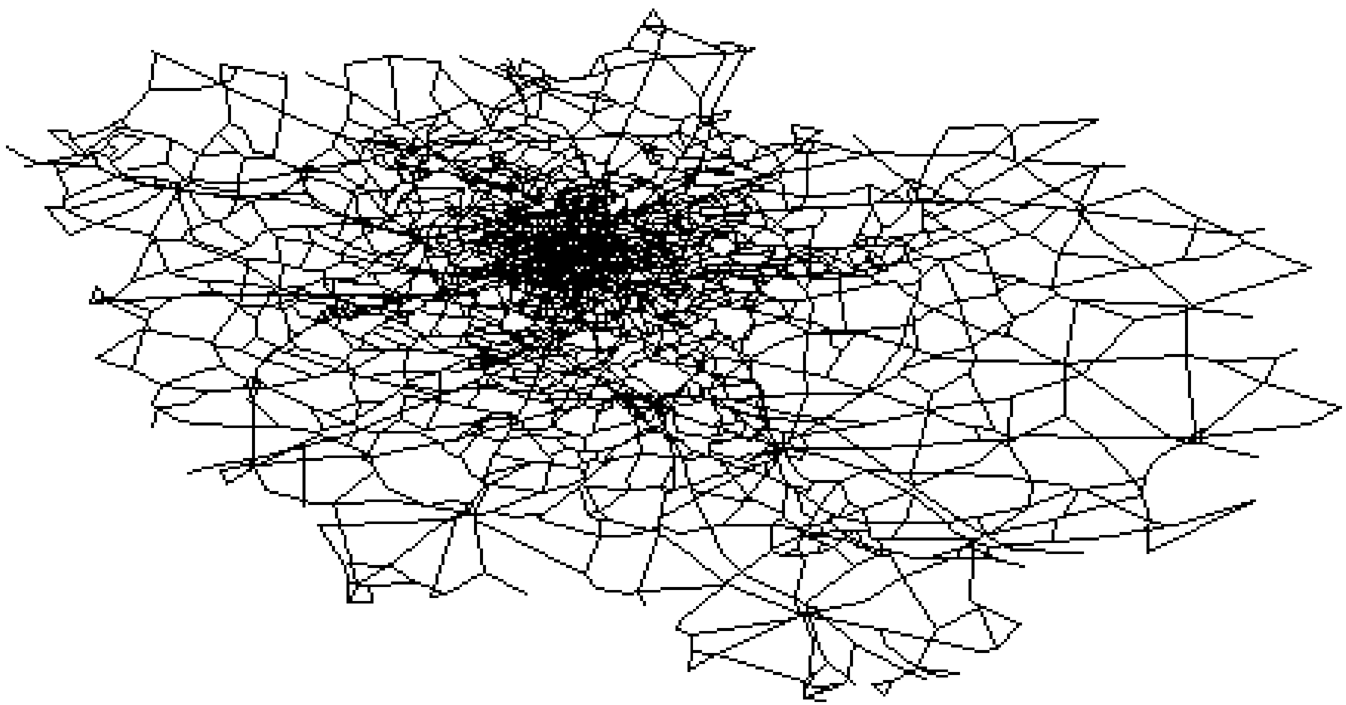
- Each grid cell contains several links

- The links are either entirely within a grid cell or pass by 2 or more grid cells.

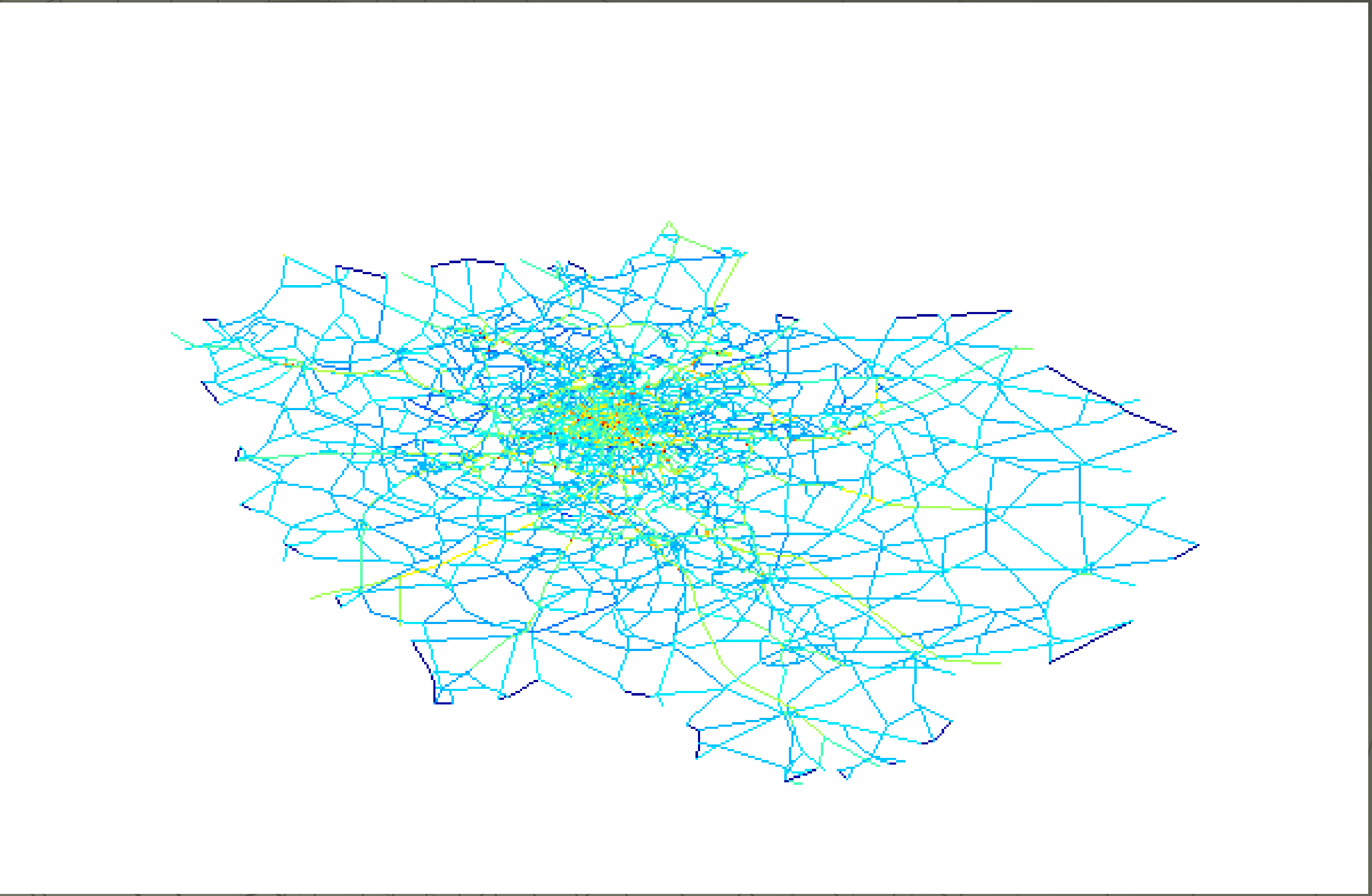
Grid cell emission is calculated by multiplying link emissions by the fraction of links in each grid cell and then added up

Color codes: blue (low emission), red (high emission)

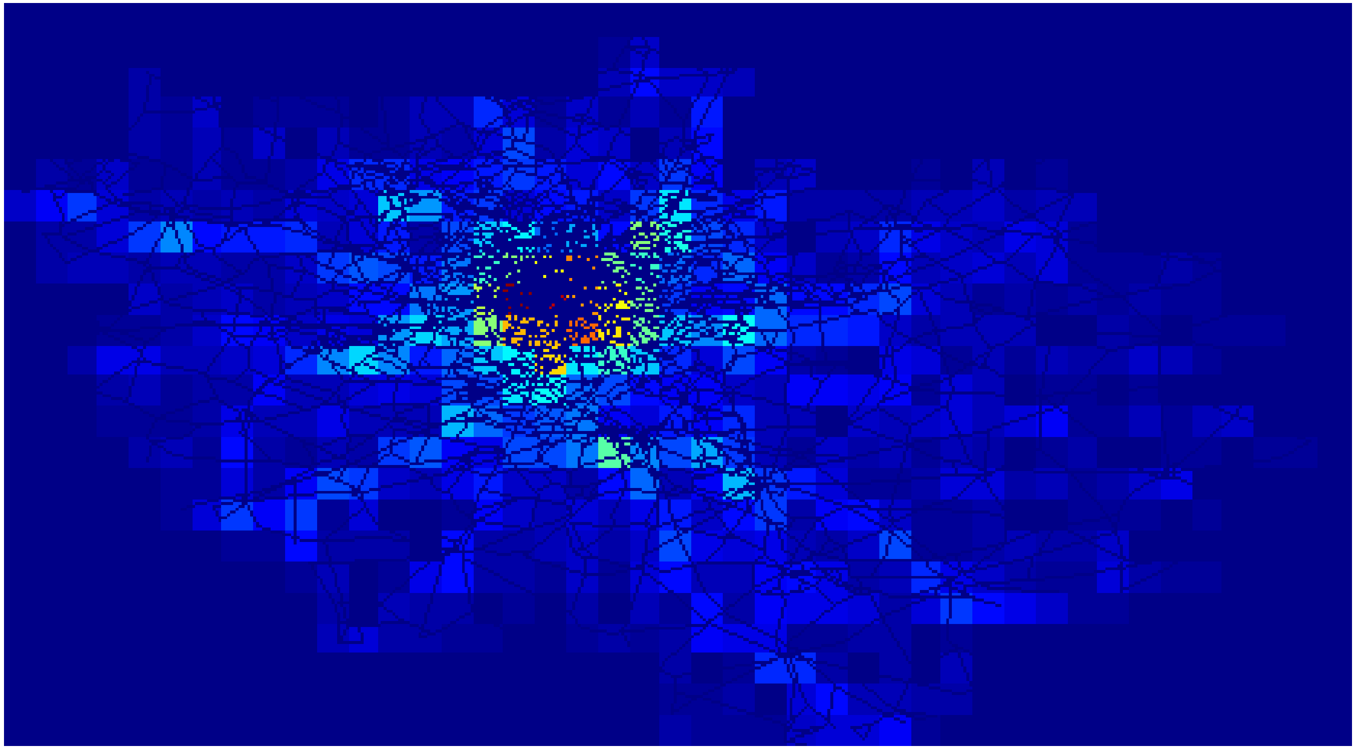
Road network - Île de France (Paris and all suburbs)



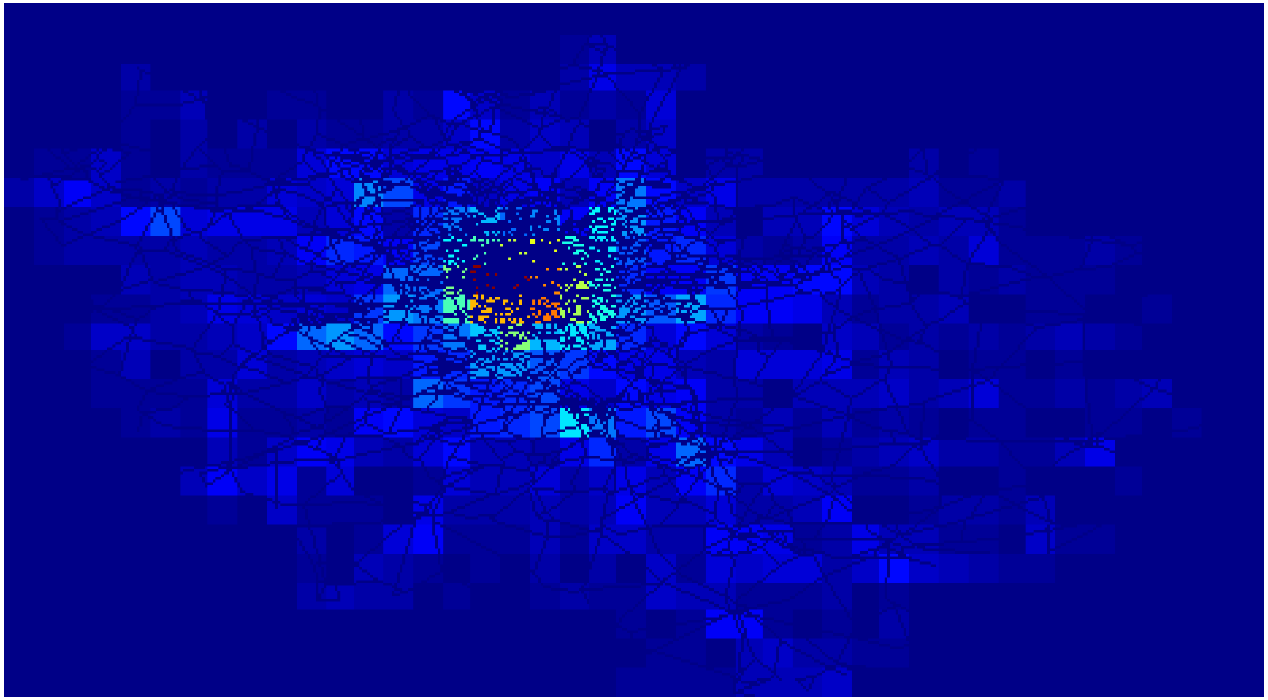
CO emissions – grams- private cars – gasoline- Île de France– at 8h00 a.m.- by link



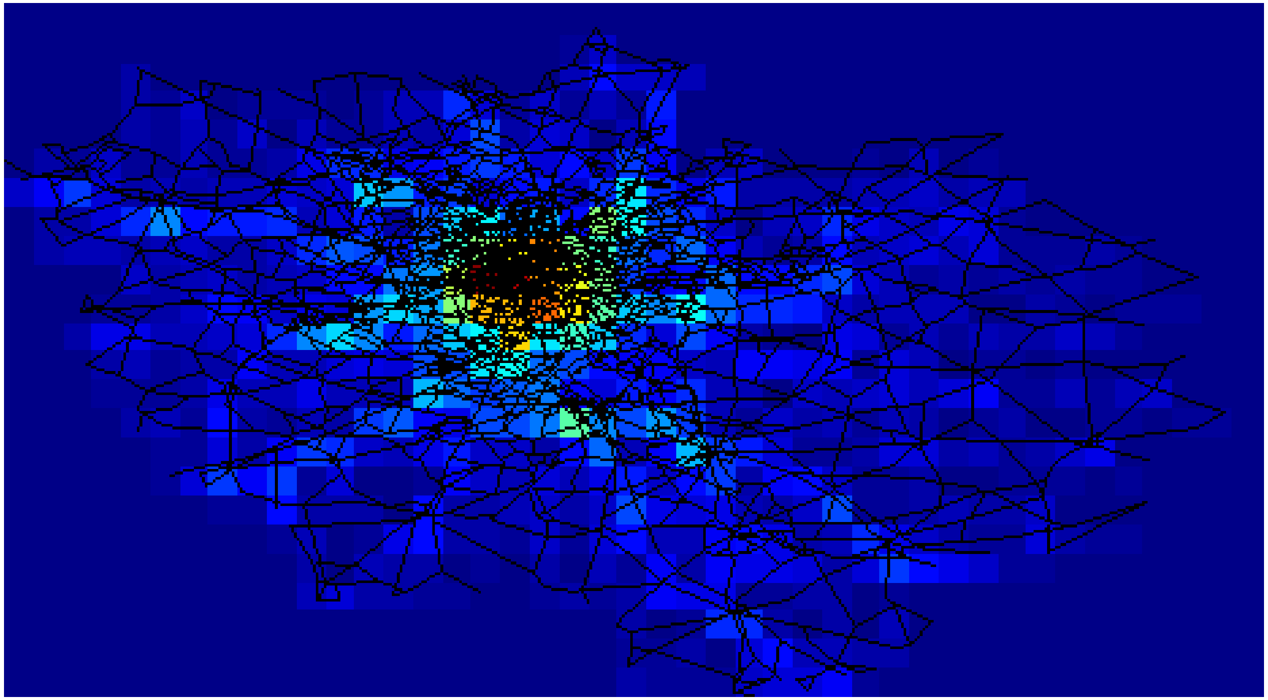
CO emissions – in grams- trucks – diesel- Île de France– at 7h00 a.m.- by grid cell



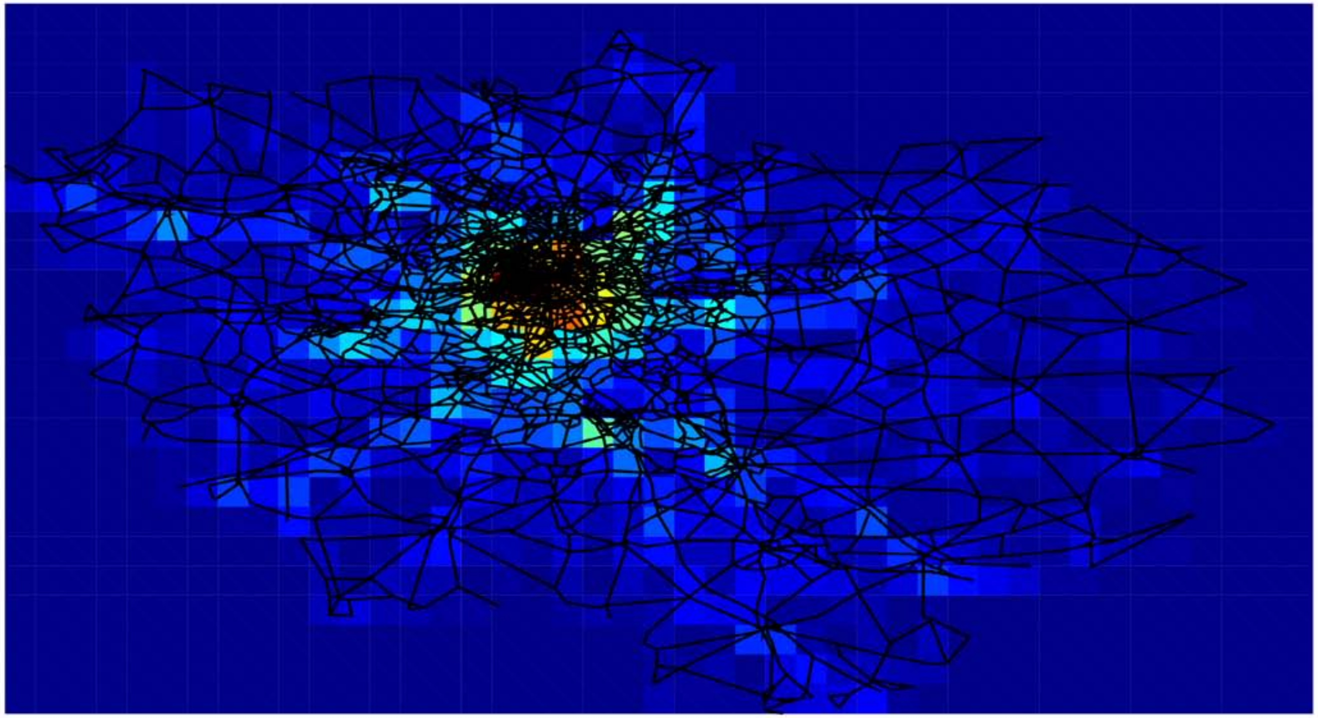
CO emissions – in grams- private cars – gasoline – Île de France – at 7h00 a.m.– by grid cell



NOx emission– grams- trucks– diesel - Île de France– à 7h00 - by grid cell



NOx emission – grams- cars – gasoline - Île de France– at 7h00 a.m. by grid cell



Dynamic assignment, trip chaining, parking and cold emissions : DYNABURBS

DYNABURBS : Dynamic Assignment for Suburbs

A dynamic assignment model with trip chaining and parking option.

trip chaining is defined as the number of stops a road user makes between an origin and destination due to non-work activities (example: dropping kids to school, shopping, docotor's appointment, or cultural and recreational activities).

The output of the Dynamic Assignment coupled with trip chaining and parking option model is used in cold emission estimation

DYNABURBS : Dynamic Assignment for Suburbs

Network characteristics:

DYNABURBS is designed for networks that connect a small number of origins and destinations such as networks that connects suburbs to suburbs or suburbs to city centers.

The arcs of such networks are usually urban roads that allow road side and /or garage parking

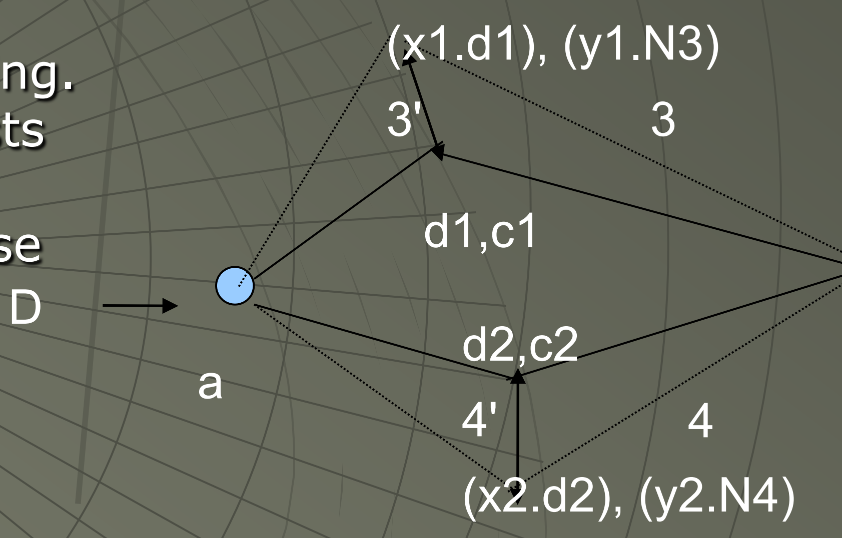
DYNABURBS : Dynamic Assignment for Suburbs

An example: origin (a) and destination (b)

Origin (a) is connected to destination (b) by two arcs (1) et (2).

The two auxiliary arcs (3) and (4) represent parking(either curb side parking or garage parking)

arcs (3'), and (4') are « dummy » links and represent access to parking. No travel time costs or parking costs are associated with these dummy links. Users can enter and exit these arcs free of charge.



Total demand = D

D = d1 + d2

c1(d1) = cost of driving on arc (1) which is the function of demand on that arc.

DYNABURBS : Dynamic Assignment for Suburbs

c2(d2) = Cost of traveling on arc (2)

x1 = Fraction of users that exit the main traffic on arc (1) and park on link (3) (0<x1<=D)

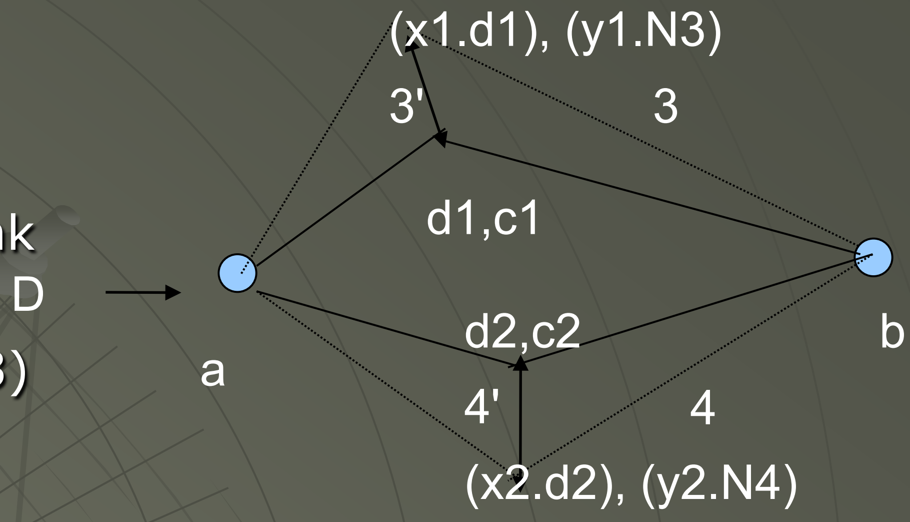
y1 = Fraction of users that exit arc (3) and enter the main traffic on arc (1) (0<y1<=D)

N3 = Number of parking spots occupied on arc (3)

x2 = Fraction of users that exit arc (4) and enter the main traffic on arc (2) (0<x2<=D)

Y2 = Fraction of users that exit arc (4) and enter the main traffic on arc (2) (0<y2<=D)

N4 = Number of parking spots occupied on arc (4)

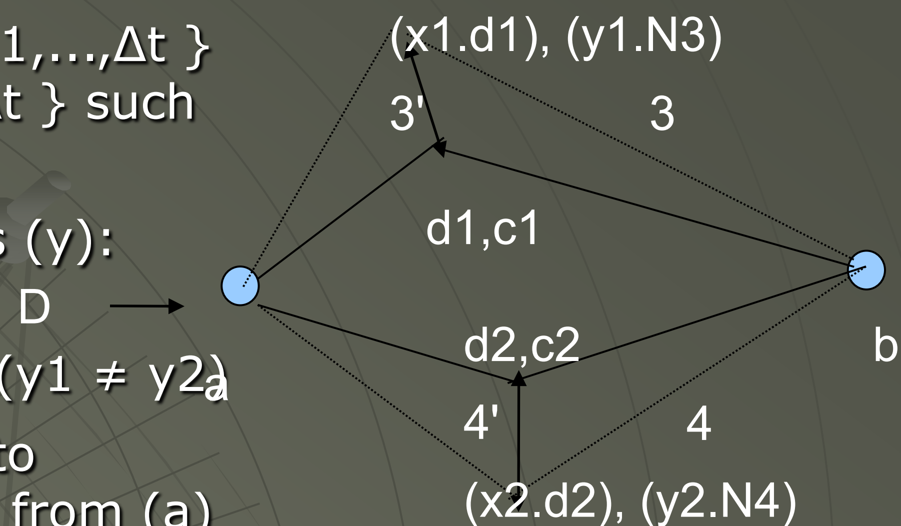


DYNABURBS : Dynamic Assignment for Suburbs

- During each time interval: (Δt)

there exist a fraction of users {$x1(t)$, $t=1,\ldots,\Delta t$ } and a fraction of users {$x2(t)$ $t=1,\ldots,\Delta t$ } such that ($x1 \neq x2$)

- Similarly there exist a fraction of users (y): {$y1(t)$, $t=1,\ldots,\Delta t$ } and a fraction
- of users {$y2(t)$ $t=1,\ldots,\Delta t$ } such that ($y1 \neq y2$)



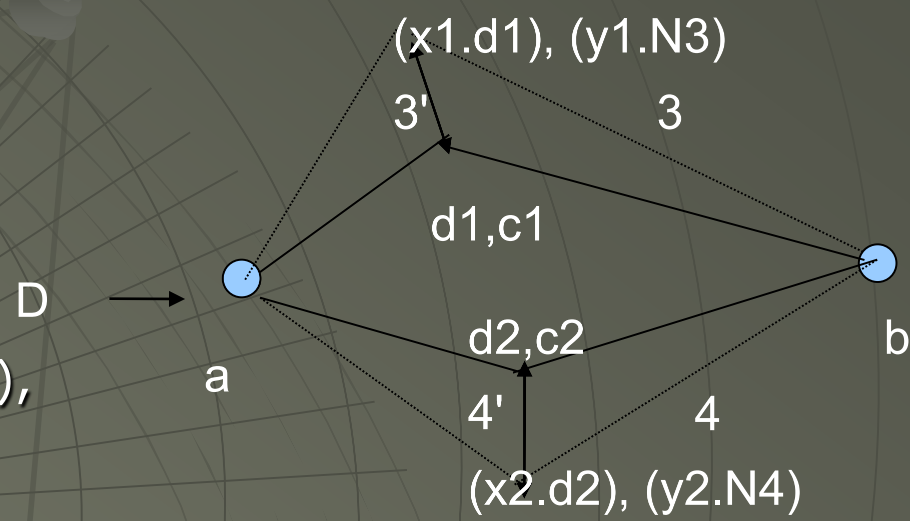
- Dynamic assignment in this context: to distribute the number of users that go from (a) to (b) during each time interval (Δt) between arcs (1),and (2) in such a way that the network is at equilibrium (costs on arcs (1), and (2) are equal, given the parking option represented by arcs (3), and (4).
- The idea is: that (x) et (y) are random variables, and as a consequence the number of vehicles parked are also variables.
- Users that leave parking during the time interval (Δt) enter the main traffic stream at rate (y).

DYNABURBS : Dynamic Assignment for Suburbs

The outcome of a dynamic assignment model gives:

$$c1(d1(t),t) = c2(d2(t),t)$$

volumes $d_e1(t)$, and $d_e2(t)$, speeds ($v_e1(t)$ et $v_e2(t)$) are values at equilibrium and so are $N_e3(t)$, $N_e4(t)$, the number of cars parked on arcs (3), and (4)

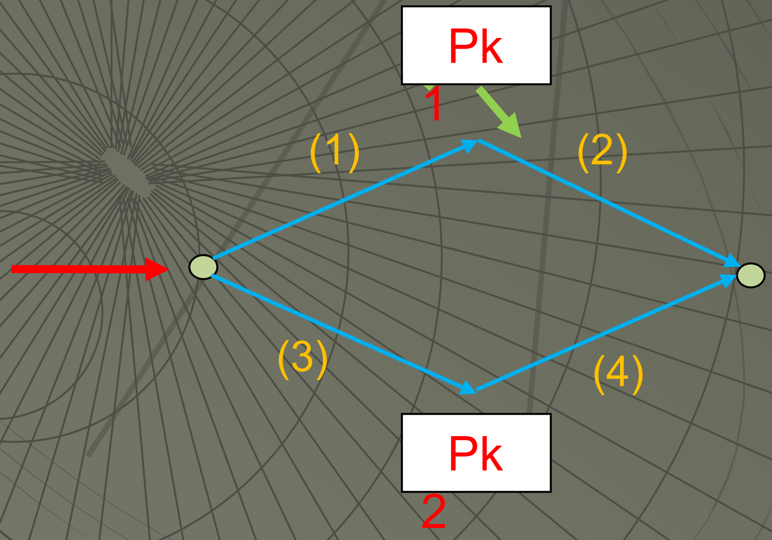


example: $y1 * N_e3(t)$ = the volume of traffic that runs on cold engine and enters arc (1) at network equilibrium

Program DYNABURBS

Application of DYNABURBS: a simple network

- (1) two types of users: those who go from an origin to a destination without stopping on the way , those who park in between the origin and the destination
- (2) there are two trip chaining possibilities: either parking at (origin-destination) or parking at parking lot (1) or (2).
- (3) vehicle type: private cars running on gasoline and diesel
- (4) possibility of parking on each arc



DYNABURBS

(5) Parking rate is assumed to be fixed at (φ)

(6) The exit rate from a parking garage or a side street parking spot is fixed at (ν)

(7) The number of vehicles parked in a garage or alongside streets is (N1) and (N2) vary as a function of vehicles that enter and exit the parking

$$\frac{dN}{dt} = \varphi * d - \nu * N$$

(8) The « Wardrop « equilibrium concept is used which means that if links are used then they have to have the same cost

$$C1(d_1) = C2(d_2)$$

$$D = d_1 + d_2$$

(9) The Jin method is used to calculate the Wardrop equilibrium

$$\frac{dd_i}{dt} = -d_i\left(C_i(d_i) - \overline{C}\right)$$

$$\overline{C} = \frac{\sum d_i * (C_i(d_i))}{D}$$

DYNABURBS

The procedure applied is as follows:

- pathFlows at equilibrium are calculated

- The number of cars parked at equilibrium are calculated

- The number of vehicles running on cold engine at equilibrium: these are vehicles that leave the parking after starting their engines, are calculated

- At network equilibrium cold emissions and hot emissions of pollutants are calculated

At dynamic equilibrium:

- the number of vehicles parked vary in time
- The number of vehicles parked affects the equilibrium which means that during each time interval a new network equilibrium is calculated as a function of the number of cars parked in the previous interval.
- since cold emissions are calculated as functions of vehicles parked, then cold emissions change during each time interval

An exemple of DYNABURBS

- the simple network with two links is revisited:
- Running DYNABURBS (in Scilab) gives the following results:

given D = 5400 cars

- Phi = fraction of vehicles that park at equilibrium

arc (1) = 0.3406603 arc(3) = 0.1163102

- Nu = fraction of vehicles that enter the traffic stream after being parked

arc (2) = 0.4663210 arc(4) = 0.3439935

PathFlows = traffic volume at equilibrium

(1) + (2) = 3425.2019 (3) + (4) = 1974.7981

An example of DYNABURBS

NbVhPk = number of vehicles parked at equilibrium

1492.7815 865.49751

Nu(2)*NbVhPk (2) = number of vehicles running on cold engine on arc (2)

608.43883

Emission_Vl_gas_H_CO = hot emission of CO – gasoline (grams)

1141.5196 2671.2764 1905.7792 1055.2549

Emission_Vl_gas_C_CO = cold emission of CO – gasoline (grams)

3454.2036 1750.3366 12803.709 816.55459

Emission_Vl_dis_C_CO = hot emission of CO – diesel (grams)

108.57572 24.647047 50.337814 9.6717734

Emission_Vl_dis_H_CO = cold mission of CO – diesel (grams)

410.53761 498.07075 288.21765 178.08296

DYNABURBS

observations:

- as the volume of traffic varies in time, the number of vehicles parked (N) vary accordingly.

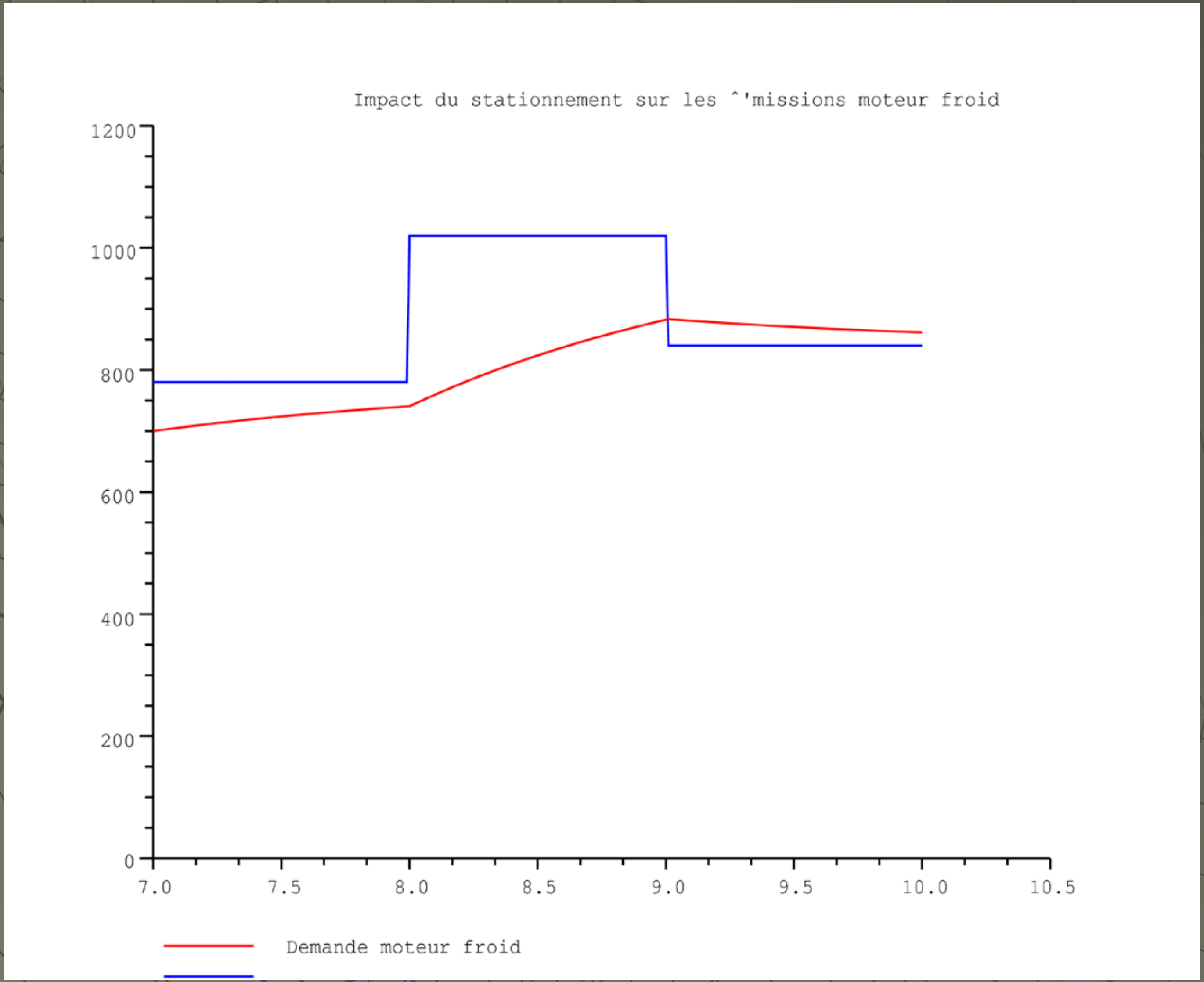
- the number of vehicles running on cold engine is equal to the number of vehicles that have left parking garages and side streets parking places

- if the number of vehicles running on cold engine were estimated as (φ x demand), this estimation would have given systematic errors

- Thus, the number of vehicles parked (N) should be calculated first and the number of vehicles running on cold engine should be calculated as a function of (N)

DYNABURBS

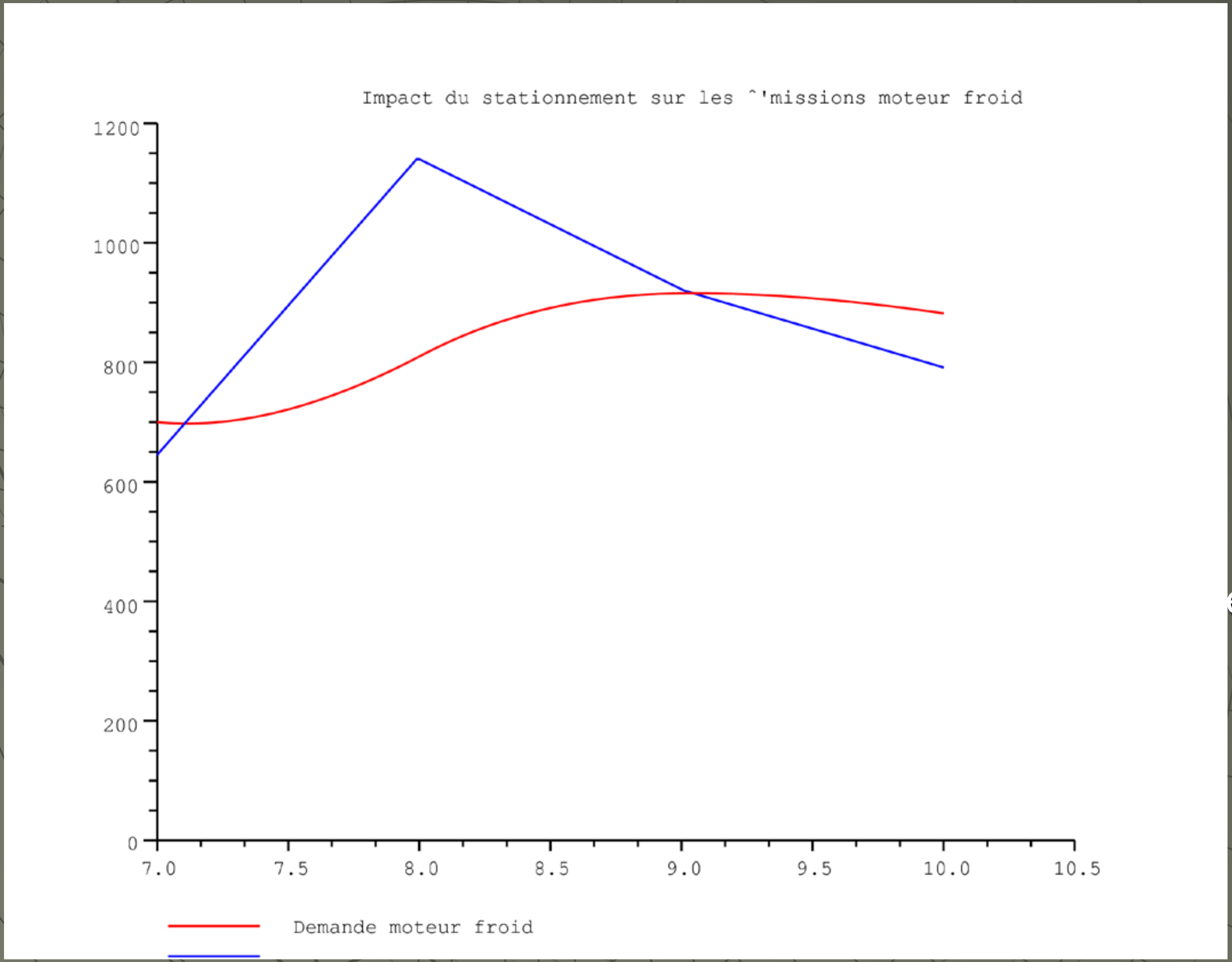
The impact of time varying parking pattern on cold emission estimation:



x-axis is time and y-axis is cold emissions. Blue line represents cold emissions based on link flows which are piece wise constant functions of time . Red line represents cold emissions based on link flows and parking

DYNABURBS

The impact of time varying parking pattern on cold emission estimation:



x-axis is time and y-axis is cold emission. Blue line represents cold emissions based on link flows which are piece wise linear functions of time . Red line represents cold emissions based on link flows and parking

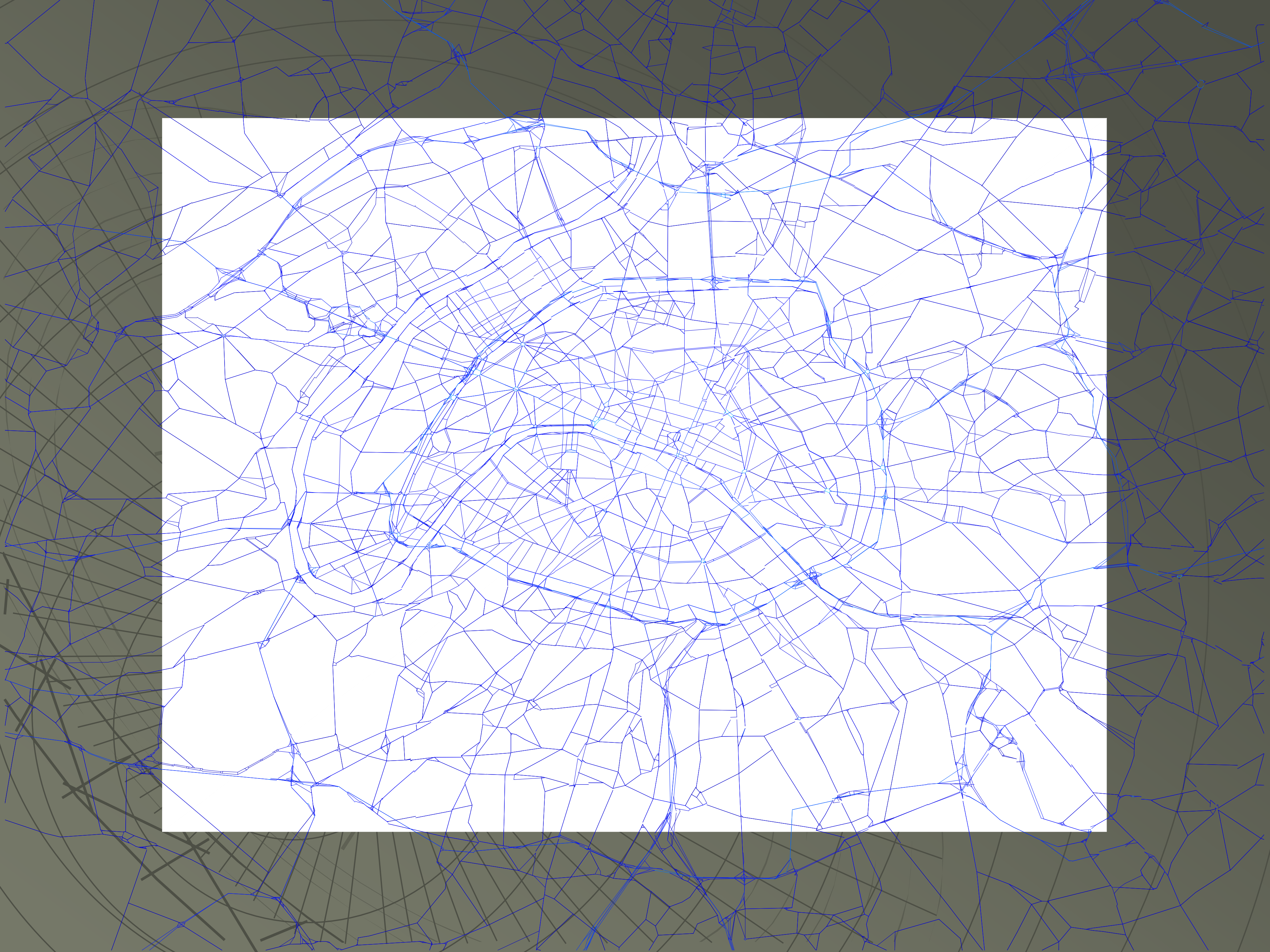
Pollutant emission.

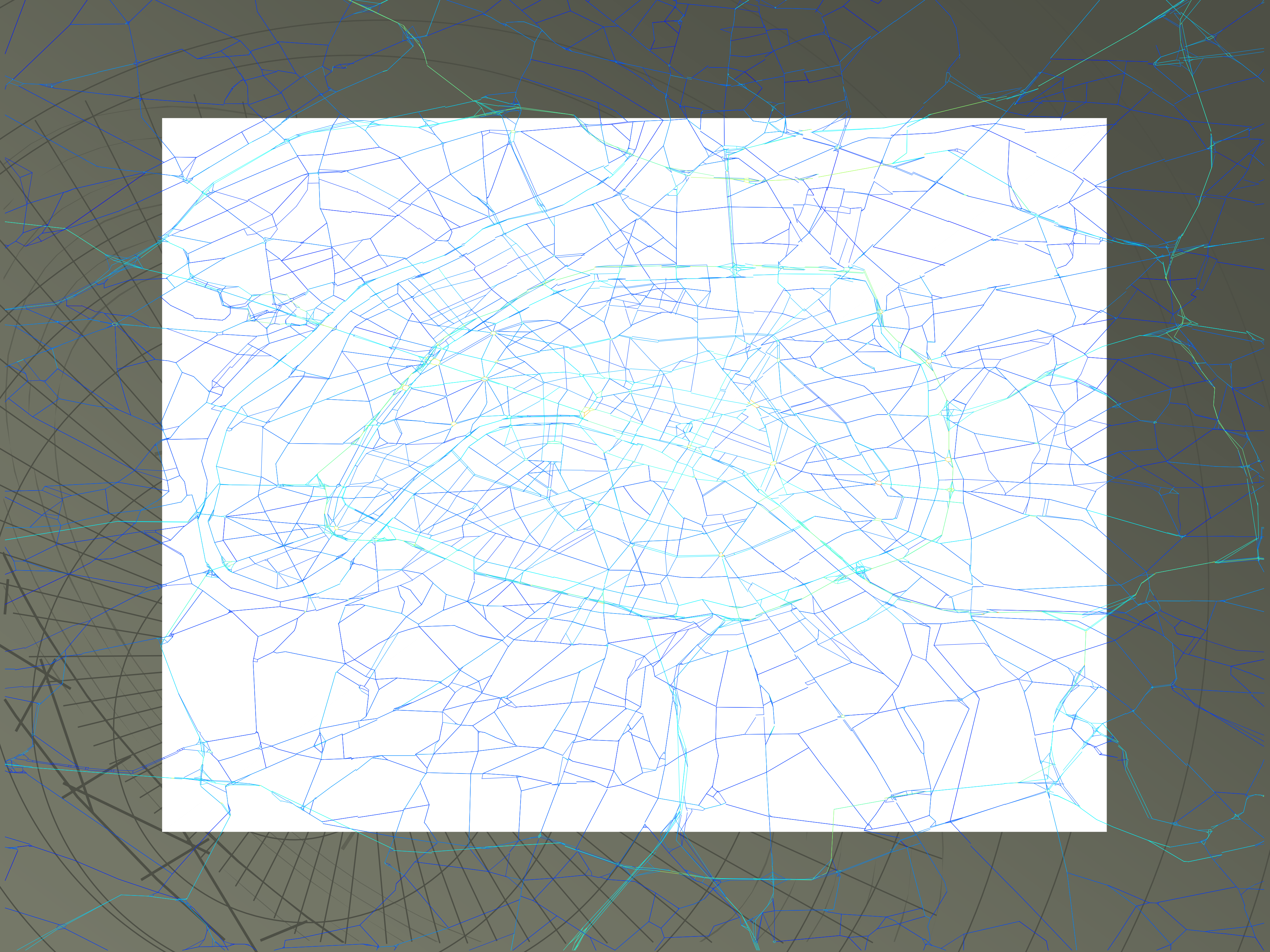
Paris area, morning (6 to 9 pm)

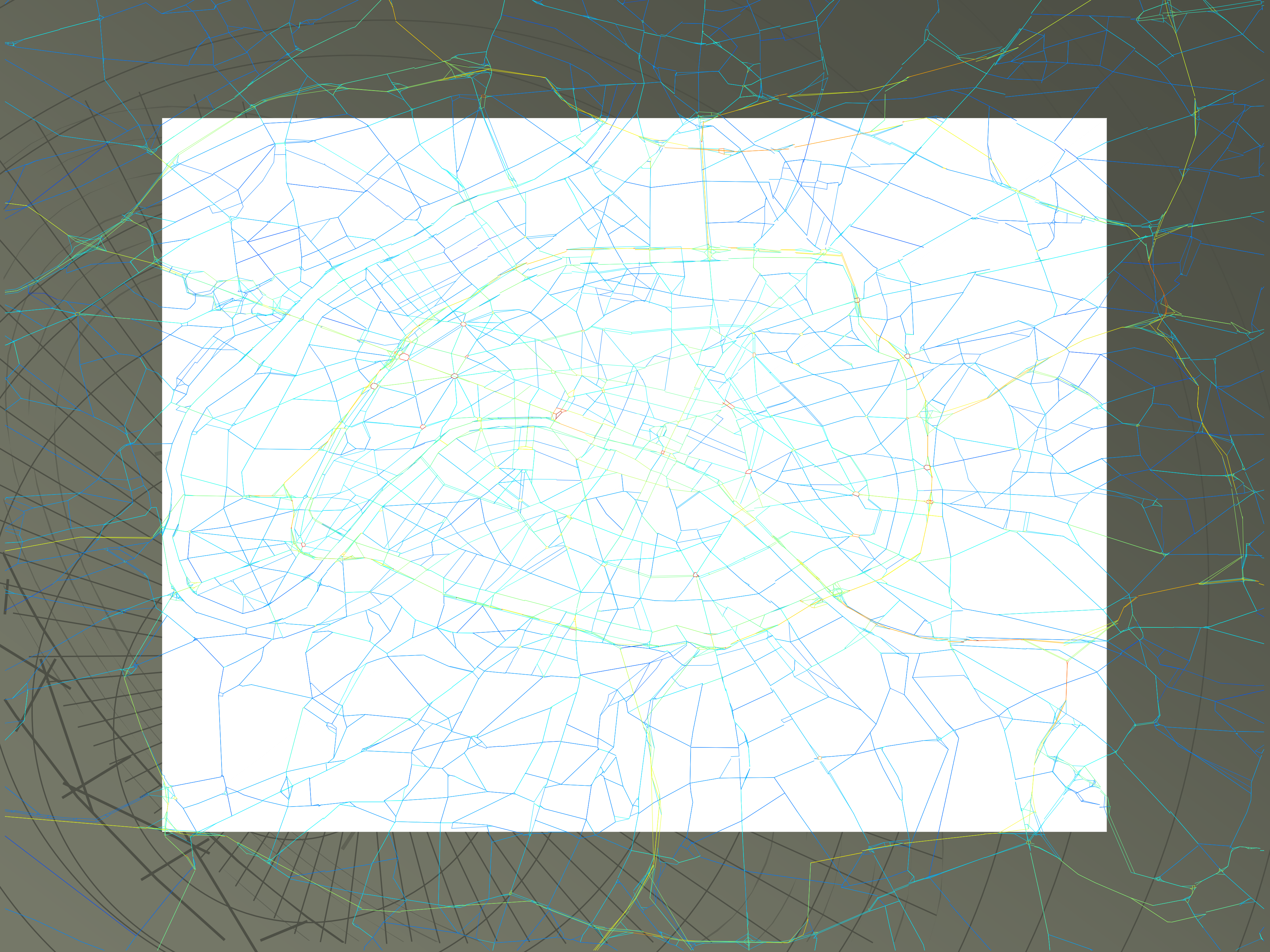
CO emissions (hot and cold emissions)

Dynamic traffic volume, speeds, parking

Cars running on gasoline







Correction factors in REALITY

There are two variables in the model that can be corrected using correction factors:

- Basic emission rates (BER) are functions of speed.

The question is which speed equation to use, and whether the speed function chosen is representative of what goes on the roads ?

- how to apply correction factors to speed measurements?
- let's denote the speed correction factor by (SCF). what method should be used in determining correction factors ?

- extreme Temperatures impact speeds. Thus accurate temperature measurement and correction factors are needed. Let's denote the temperature correction factor by (TCF)

Correction factors in REALITY

- which speed equations to choose for BER calculation?

The approach used is « bootstrapping & confidence interval method »

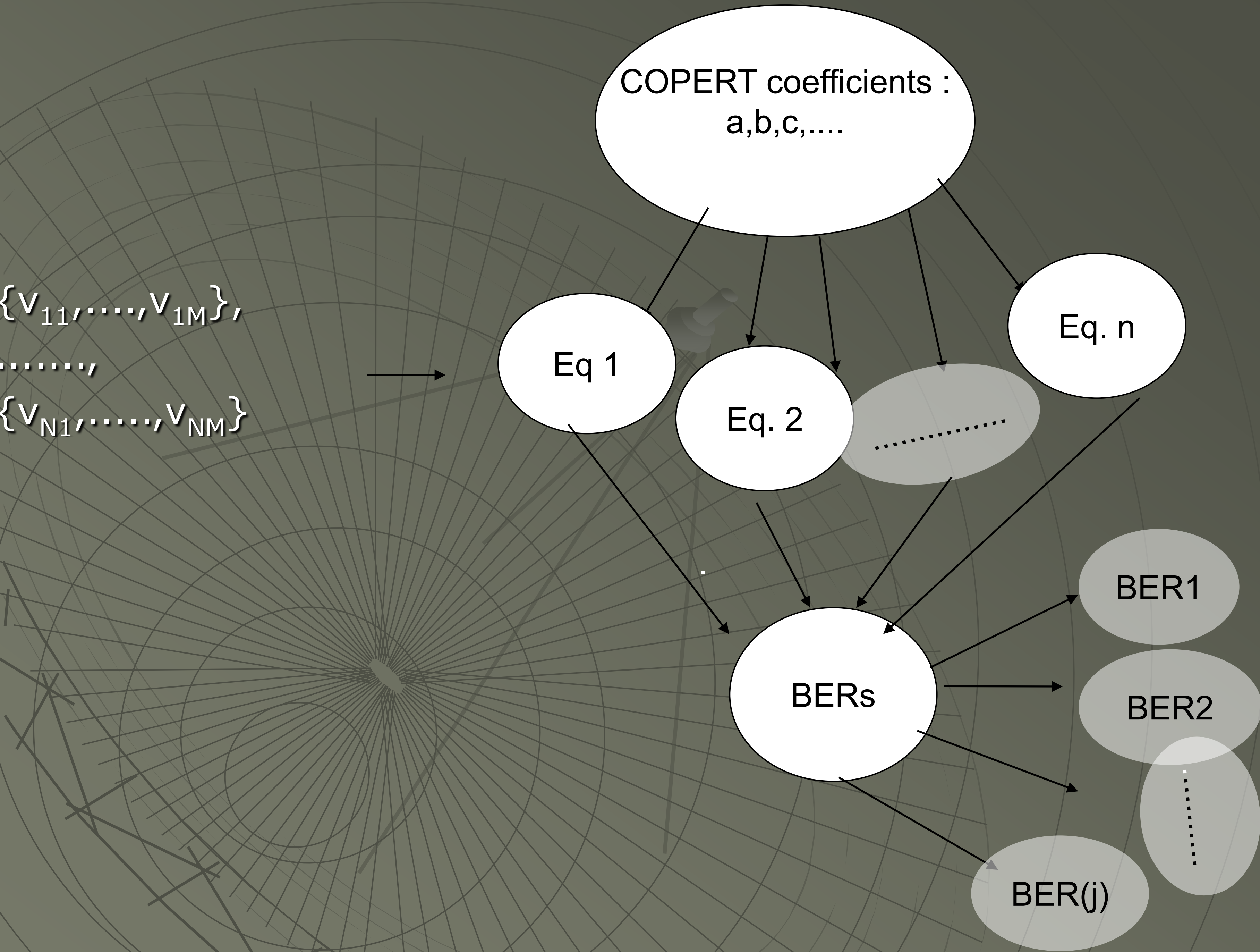
i = number of samples ; $i = \{1,\ldots,N\}$ = (example: different places in a road network)

j = the number of arcs in each sample (i); $j=M$, (all samples have a fix number of arcs)

v_{ij} = a matrix of average speeds

example: $\{v_{11},\ldots,v_{1M}\}$, v_{1M} = average speed in sample (1), on arc (M);

In general: v_{ij} = average speed in sample (i) , arc (j);
$i=1,..,N$; $j= 1,\ldots,M$


{v11,....,v1M},
.......,
{vN1,.....,vNM}
COPERT coefficients : a,b,c,....
Eq 1
Eq. 2
Eq. n
BERs
BER1
BER2
BER(j)

Correction factors in REALITY

- the BERs are calculated for each of the equations (Eq.1,...Eq.n) and for each arc.

- the estimated BERs are then compared:

- If there are no variations among these estimated BERs, and among the (N) different samples, then any of the (n) equations can be used for BER estimation.

If on the other hand, there are variations among these estimated BERs, and among the (N) different samples, then:

if the BER are under estimated in comparison with other sources of BER estimation, then let's denote these BERs by (e^{l}_{i})

- apply SCF to average speeds

- modify coefficients (a,b,c,...) by adding white noise (normally distributed $N(0, \sigma^2)$)

- recalculate BERs , if no variations, then can choose among any of the modified equations, otherwise, repeat the process until convergence obtained.

Correction factors in REALITY

- if the BERs are over estimated in comparison with other sources of BER estimation, then let's denote these BERs by (e^h_i)
  - apply SCF to average speeds
  - modify coefficients (a,b,c,...) by adding white noise (normally distributed N(0, σ^2)
  - recalculate BERs , if no variations, then can choose among any of the modified equations, otherwise, repeat the process until convergence.
- if the BERs are either under estimated and over estimated in comparison with other sources of BER estimation, then let's denote these BERs by (e^v_i)
  - apply SCF to average speeds
  - modify coefficients (a,b,c,...) by adding white noise (normally distributed N(0, σ^2)
  - recalculate BERs , if no variations, then can choose among any of the modified equations, otherwise, repeat the process until convergence.

Correction factors in REALITY

- Calculation of mean BERs for each sample:

$$\bar{t}_i = \frac{\sum_{j=1}^{M} \left(e_j^v\right)}{M} \quad i = 1,\ldots,N$$

t_i^- = mean BER per sample
M = number of arcs in each sample
e^v_j = BER values: v = signifies either over or under estimation

- Calculation of variance and standard deviation for each sample:

$$S_i^2 = \frac{1}{(M-1)} \sum_{j=1}^{M} \left(e_j^v - \bar{t}_i\right) \quad i = 1,\ldots,N$$

$$s = \sqrt{S_i^2}$$

S^2 = variance

s = standard deviation

Correction factors in REALITY

$$\bar{t} = \sum_{i=1}^{N} \bar{t}_i$$

$\bar{t}$ = total mean BER

$\bar{t}_i$ = mean BERs per sample

- Confidence interval

$$\left(\bar{t} \mp 0.90\left(\frac{s}{\sqrt{N}}\right)\right)$$

- The BERs are recalculated applying SCF to adjust speeds:
- if the recalculated BERs fall in the confidence interval, then any of the speed equations used to calculate BERs are acceptable .

Speed correction factor: (SCF)

- « bootstrapping » and« condifence interval methods are used in finding the speed correction factor.

- Several data samples are taken:

  - for example average speeds resulting from several runs of a dynamic assignment model.

    - let $i = 1, \ldots, K$; be the number of data sets

      K = the maximum number of samples

  - each data set contains a fixed number of arcs

- Though the number of links are fixed, their types vary from highways, and expressways to urban streets.

  let $x_{11}, \ldots, x_{M1}$; x_{Mi} be average speeds on each link (i)

Correction factors: speed (SCF)

- Average speed is calculated as the mean of all link average speeds

$$\bar{x}_i = \frac{\left(x_{1,i} + \ldots + x_{M,i}\right)}{M}$$

$$i = 1, \ldots, K$$

- Let $x_{M,i} \sim N(0, \sigma^2)$ be normally distributed
- calculation of residuals:

$$e_i = \left(x_i - \bar{x}_i\right)^2$$

- let $e_i \sim \sigma^2 \chi 2\ (M-1)$ have a chi distribution with (M-1) degrees of freedom
- If the population standard deviation is known, (σ), the confidence interval can then be calculated:
- Total average speed for all samples

$$\bar{x} = \frac{\sum_{i=1}^{K} \bar{x}_i}{K}$$

Correction factors: speed (SCF)

- The statistic (Z): $$Z = \frac{(\bar{x} - \mu)}{\left(\frac{\sigma}{\sqrt{K}}\right)}$$

- if 1 – α = 0.95 (95% confidence interval)

$$P(-z \le Z \le z)1 - \alpha = 1 - 0.95$$

$$\varphi(z)P(Z \le z)1 - \frac{\alpha}{2} = 0.975$$

$$z = \varphi^{-1}(\varphi(z)) = \varphi^{-1}(0.975) = 1.96$$

$$0.95 = 1 - \alpha = P\left(-1.96 \le \frac{(\bar{x} - \mu)}{\left(\frac{\sigma}{\sqrt{K}}\right)} \le 1.96\right)$$

$$P\left(\bar{x} - 1.96\left(\frac{\sigma}{\sqrt{K}}\right) \le \mu \le \bar{x} + 1.96\left(\frac{\sigma}{\sqrt{K}}\right)\right)$$

-μ is the population mean

Correction factors: speed (SCF)

-the confidence interval is

$$\left(\bar{x} - 1.96\left(\frac{\sigma}{\sqrt{K}}\right), \bar{x} + 1.96\left(\frac{\sigma}{\sqrt{K}}\right)\right)$$

- (SCF) in the case of over estimation of speed is given as:

$$SCF = \frac{1}{\left(\bar{x} - 1.96\left(\frac{\sigma}{\sqrt{K}}\right)\right)}$$

$$\tilde{v} = v^h * SCF = \frac{v}{\left(\bar{x} - 1.96\left(\frac{\sigma}{\sqrt{K}}\right)\right)}$$

v~ = adjusted (corrected)speed

v^h = over-estimated speed

Correction factors: speed (SCF)

- The speed correction factor (SCF) in the case of under estimation is given

$$SCF = \left(\bar{x} + 1.96 \left(\frac{\sigma}{\sqrt{K}} \right) \right)$$

If the average speed is under estimated, then the estimated speed :v~ is given as:

$$\tilde{v} = v^{l} * SCF = v * \left(\bar{x} + 1.96 \left(\frac{\sigma}{\sqrt{K}} \right) \right)$$

v~ = corrected speed

v^l = under estimated speed

Correction factors : temperature (TCF)

- The following method is used to estimate temperature correction factor:

- for each day of the month, maximum and minimum temperatures are recorded and denoted by (T_{max}, T_{min})

- daily averages are calculated as

$$\hat{T} = \frac{\sum \left(T_{max} + T_{min} \right)}{2}$$

- Monthly average is calculated as:

$$\bar{T} = \frac{\sum \left(\hat{T} \right)}{31}$$

- standard deviation is calculated as:

$$S^2 = \frac{\sum_{i=1}^{31} \left(T_i - \bar{T} \right)}{30}$$

$$\left(n - 1 \right) = 30$$

Correction factors : temperature (TCF)

$$s = \overline{S^2}$$

- The temperature correction factor is calculated as:

$$TCF = \frac{\left(T_{obs} - \overline{T}\right)}{\left(\dfrac{s}{\sqrt{31}}\right)}$$

- If the observed or forecast temperature is greater than the monthly average, then it is corrected in the following manner:

$$T_{obs} > \overline{T}_{month}$$

$$BER_{mod} = BER_{old} * (1 + TCF) \quad \left(mod = modifier\right)$$

$$T_{obs} < \overline{T}_{month}$$

$$BER_{mod} = BER_{old} * (1 + TCF)$$

Pollutant concentration for a road network

- the conventional method :
  - each of the links of a road network is considered a linear source of pollution – (line source modeling)

  - Only those links are considered that have the « urban street canyons » effect
  - mathematical models used in calculating linear micro scale pollution concentration:

  Street canyon models

  Building wake models are two examples of this type of modeling

(source: Sprin, A. Air Quality at street level: Strategies for Urban Design. Cambridge: Harvard Graduate School of design (1986))

- significant factors:
  - Pollutant emission levels
  - Air circulation, depends on the wind, its speed and temperature
  - Street isolation level: is defined by the shape and the height of buildings that surround the street
  - Absorption rate of pollutant particles by different materials in the environment such as building materials, materials used to pave roads, etc.

Road level pollutant concentration: APOLARIS

APOLARIS : Atmospheric Pollution Activity-Road Initiated Source

The objective of this model is to calculate pollutant (CO, VOC, NOx, CO2, SOx) concentration from trafic emission

A car is considered to be a linear source of pollution emission

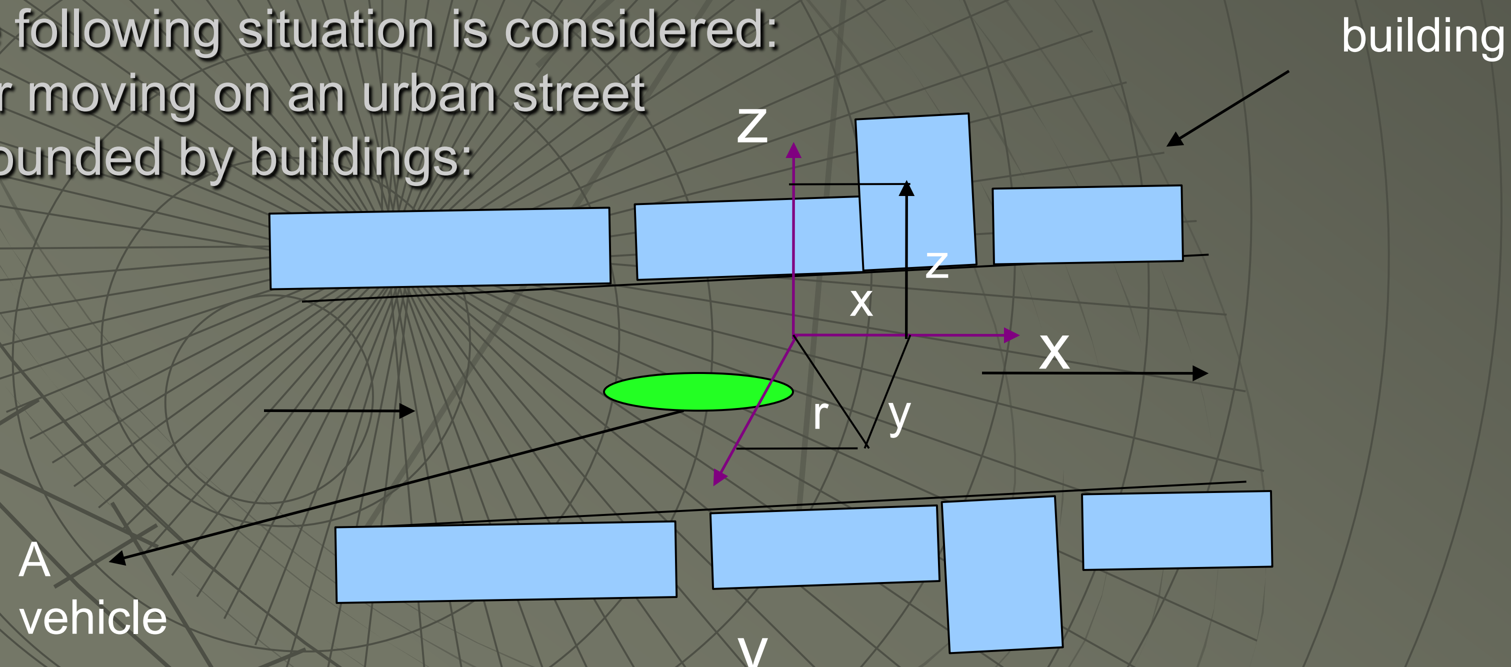
- To calculate total concentration, pollutant concentration produced on a road should be added to the pollutant concentration from fixed source emissions on that road. Fixed source emission in this context is pollution emitted from the surrounding buildings and human activities other than traffic.

Micro level pollution concentration: road pollutant Concentration estimation : APOLARIS

APOLARIS : Atmospheric Pollution Activity-Road Initiated Source

- meteorological considerations: wind intensity is assumed to be lower on urban streets. Wind intensity is assumed to be fixed during the concentration calculation.
- it is assumed that temperature is higher around urban streets .
- the following situation is considered:

a car moving on an urban street surrounded by buildings:



APOLARIS

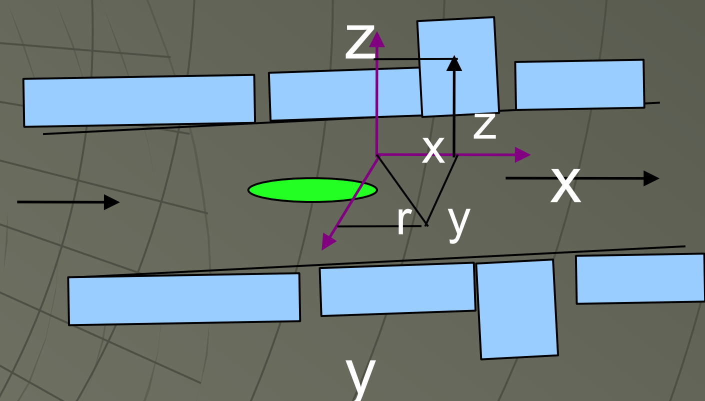
-the CTM (Chemistry Transport Model) is used to calculate road pollution concentration, but with some modifications :

$$\frac{dC}{dt} + U\left(\frac{dC}{dx}\right) + V\left(\frac{dC}{dy}\right) + W\left(\frac{dC}{dz}\right)$$

$$\frac{d}{dx}\left(k_h \frac{dC}{dx}\right) + \frac{d}{dy}\left(k_h \frac{dC}{dy}\right) + \frac{d}{dz}\left(k_z \frac{dC}{dz}\right)$$

$$+ R + Q + + \Psi + (\alpha \times \Phi)$$

- 1st step: the concentration of pollutants in the (X) direction is calculated , the solution is denoted by $C_t^{i*}(x)$



APOLARIS

- 2nd step: the concentration of pollutants in the (Y) direction is calculated the solution is denoted by $C_t^{i*}(y)$
- 3rd step: the concentration of pollutants in the (Z) direction is calculated the solution is denoted by $C_t^{i*}(z)$

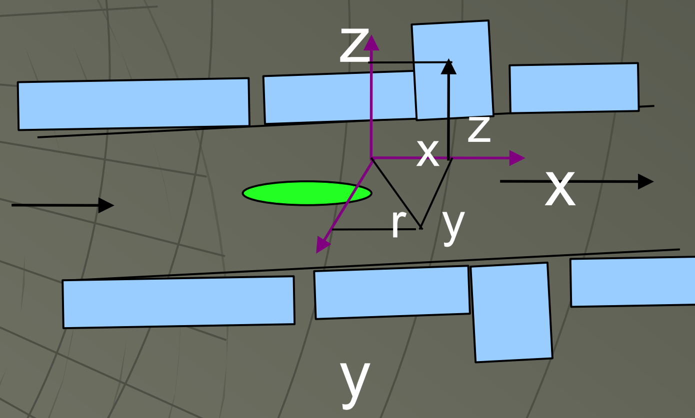
- total pollution concentration on arc (i) is calculated as:

Eigen-functions of the static part of the CTM are calculated . These eigen-functions are decomposed as products of concentration functions of x, y and z

$$C_t^{total} = C_t^{i*}(x)\, C_t^{i*}(y)\, C_t^{i*}(z)$$

So first partial one-directional problems are solved

Then the solution to the CTM is obtained as a weighted sum of the eigen-functions



APOLARIS

C = pollution concentration

U,V,W = wind components

U = wind in the east-west direction

V = wind in the north-south direction

W = wind in the vertical direction

K_h = horizontal turbulent diffusion

K_z = vertical turbulent diffusion

APOLARIS

E = represents particle movement (used in plume modeling)

R = speciation

Q = pollutant emissions from traffic = pollutant emissions on the links of a network

D = quantity of pollutants absorbed by a dry surface

W = quantity of pollutants absorbed by a wet surface

Φ = quantity of pollutants absorbed Street isolation level

α = absorption rate

Ψ = quantity of pollutants absorbed by humans: function of the density of activities

- to adapt Chemical Transport (TC) to road level :

The streets are considered as « canyon streets » and it is considered that vehicles are moving objects that have a linear trajectory

APOLARIS

- The following hypothesis are made:

- during any interval (t), wind has the components U,V,W on any arc (i)

- given that an arc is considered as « canyon street », and that there is wind, then turbulence exists and the following turbulence coefficients are considered for each arc (i) during interval (t): (K_h) and (K_z)

- the variables E=D = W = 0 for the following reasons:

  - the surface of an arc is considered to be laminated, D=W=0

  - it is considered that pollutant particles move solely due to wind intensity and no other cause; thus E=0

  - the variables Q = pollutant emissions from traffic and R = speciation, are kept