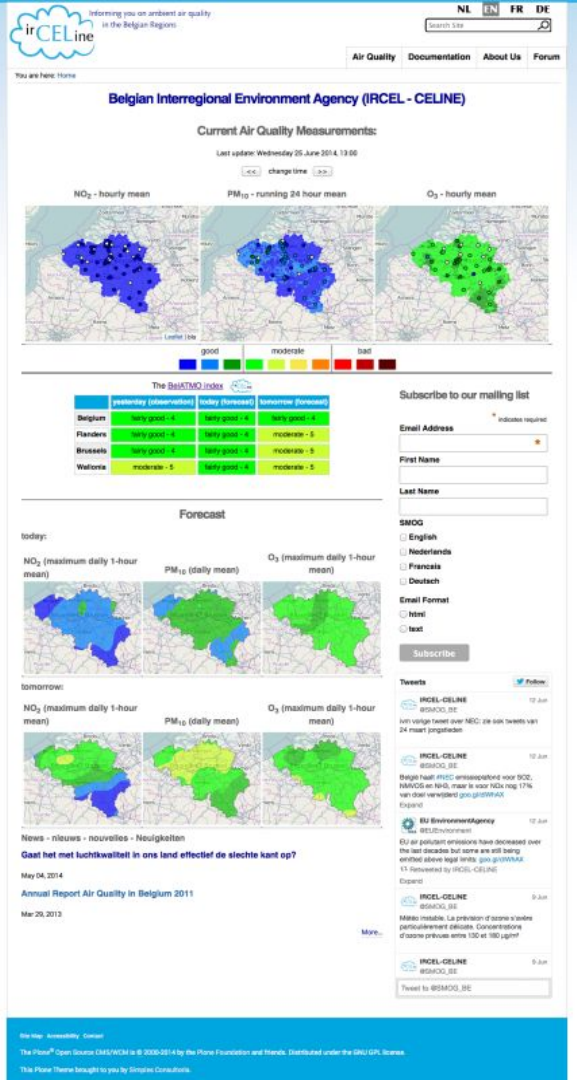
API-IMPLEMENTATION OF AIR POLLUTION MODEL DATA INTO (ROUTING)-APPLICATIONS

irCELine
Informing you on ambient air quality in the Belgian Regions

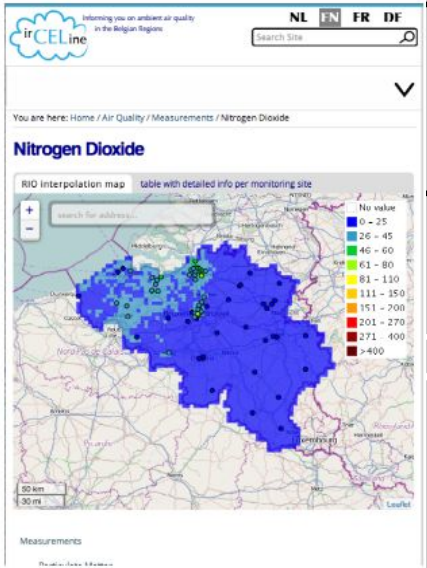
FLANDERS ENVIRONMENT AGENCY

Interreg North-West Europe
BE-GOOD

IRCEL-CELINE

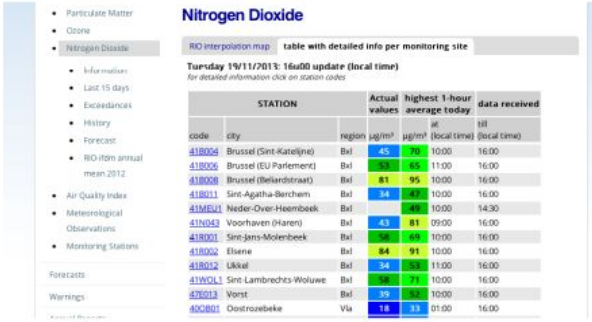


http://www.irceline.be
- Real-time data
- All major pollutants (incl. BC)
- Forecasts
- Information about pollutants
- Publications
- *etc.*

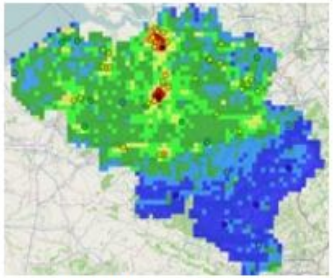


Integration of OGC-services (download and viewing) into website

… and tables with (real-time) data:

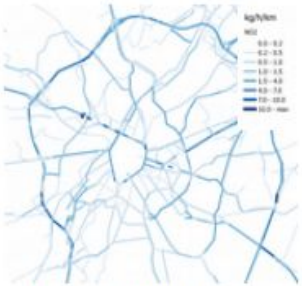


Hi resolution air quality model

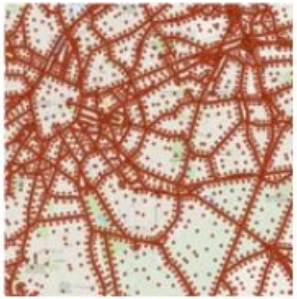


RIO
background

+



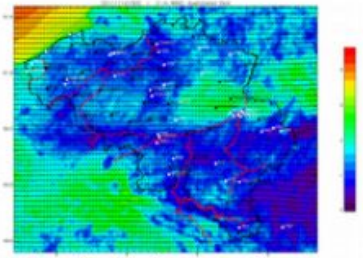
Line source
emissions



Grid of receptor
points

IFDM

+



Assimilated meteo

+

Point source
emissions

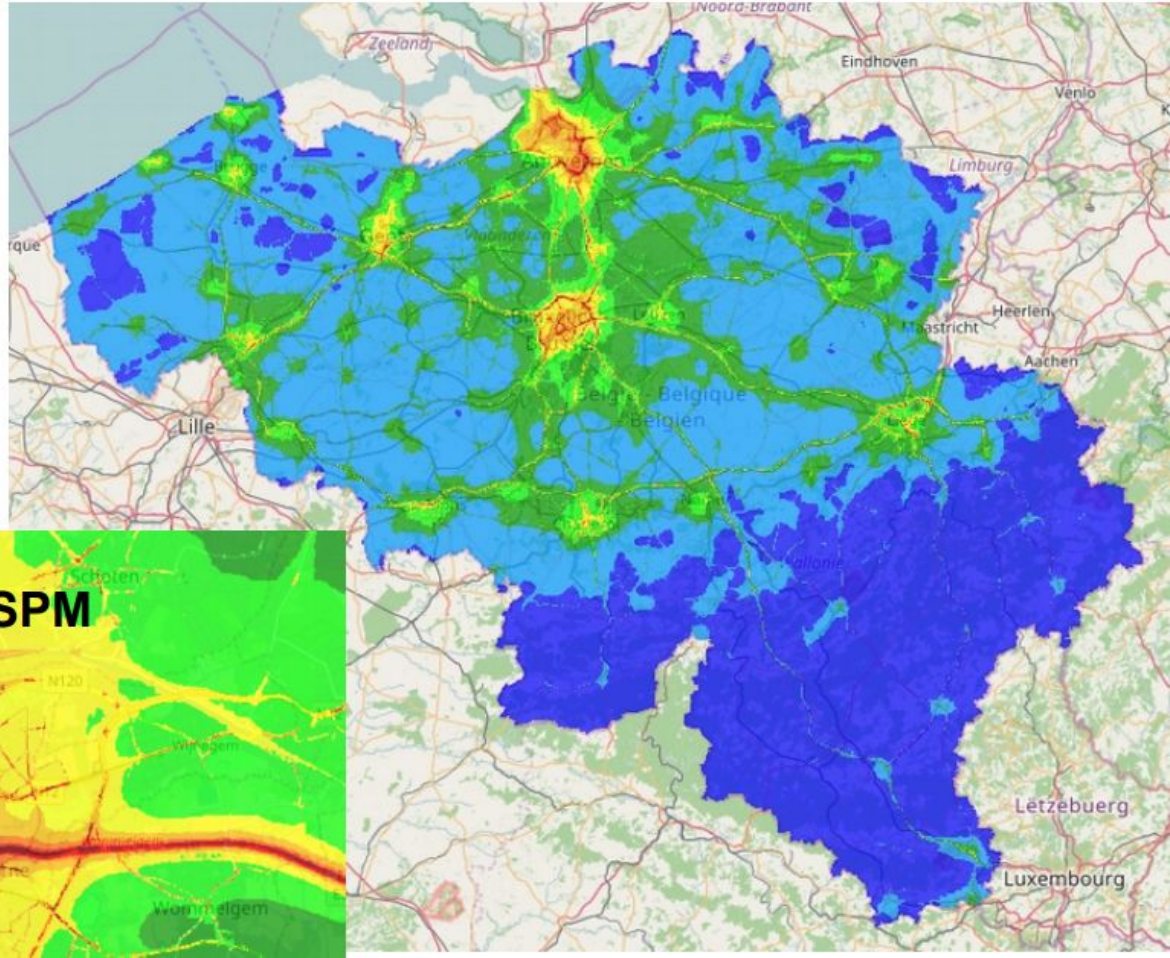
Hourly RIO-IFDM
Air Quality Index

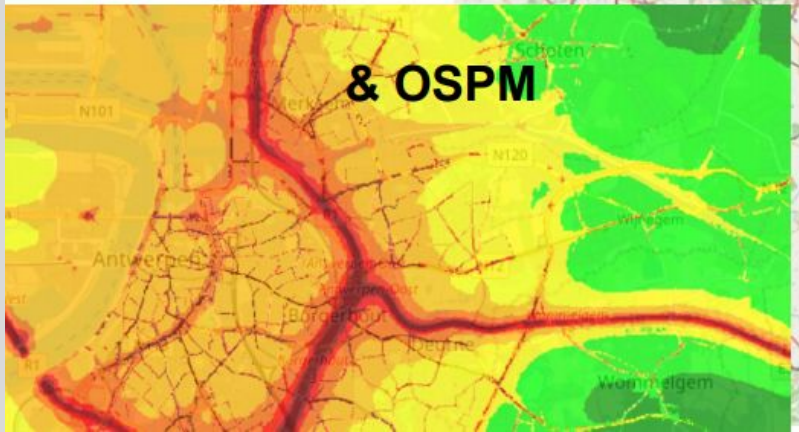
Hi resolution model (RIO-IFDM)

Nitrogen dioxide
(NO2)
annual mean

microgram/m³

- 0 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 35
- 36 - 40
- 41 - 45
- 46 - 50
- > 50





FUTURE MODEL IMPROVEMENT?

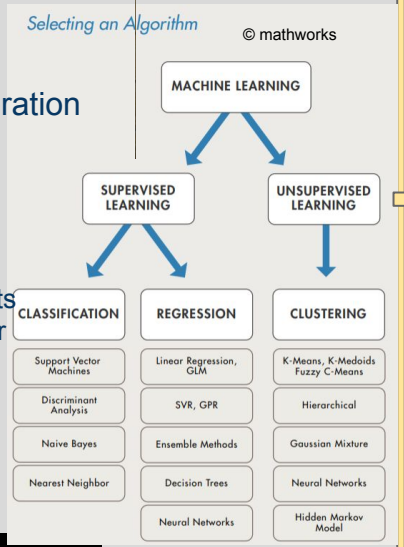
Citizens science measurement campaign (20000 samples across Flanders)

Further model improvement based on measurements

Testing of potential of low-cost sensors

Validation & calibration

Use of measurements ‘qualified sensors’ for model improvement



Improve definition & modelling of Street Canyons

Improved traffic emission data

INTRO: WHAT?

Interreg North-West Europe BE-GOOD

Issue

The air quality on the routes you take is poor and this is not visible.

Aim

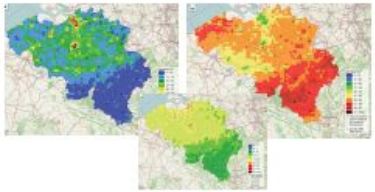
Provide a quality assured, scientifically sound data endpoint which can be used by any existing routing application to identify the healthiest route alternative.

Targeted Public

Pedestrians, cyclists, commuters, planners, the public in general.

API Healthiest Route

Context



Existing data endpoint are geared to users with sufficient expertise to interpret the information.

Need

Make impact of poor air quality more tangible to non- expert users.

Transnational Twinning

Département du Loiret and all consortium members who plan to use hackathons to refine the idea.

Necessary data

Planning and realisation

Q1-2 2017: develop data exchange model
Q1 2019: API
Q1 2020: demo implementation in a routing app

irCELine

FLANDERS ENVIRONMENT AGENCY

€ 8,000,000,000 BE

Lost work days
Sick days
Healthcare
Agriculture

Cost of air pollution (economy)

Source: European Commission

Intro:Why?

Chronic

- Lung cancer
- Brain damage
- Brain cancer
- Increase in number of asthma exacerbations

Acute

- Respiratory problems
- Acute asthma exacerbation
- Decreased lung function
- Cardiovascular problems, Heart attacks (strokes)

12,580 BE

467,000 EU

Cost of air pollution (health:deaths)

Source: European Commission

Causes of air pollution

NO_2 , BC , $PM_{2.5}$, VOC, ...

Remark: air pollution ≠ climate change
E.g. planes: very limited impact on air pollution

Air pollution ≠ CO_2

$PM_{2.5}$,$PM_{10,}$, ...

Traffic (cars, diesel cars, trucks) is by far the most important cause of air pollution exposure to pedestrians and cyclists in Flanders, followed by **households** (especially wood stoves;less important in summer). Also **agriculture** and **industry** contribute to some extent.

(1)

(2)

(3)

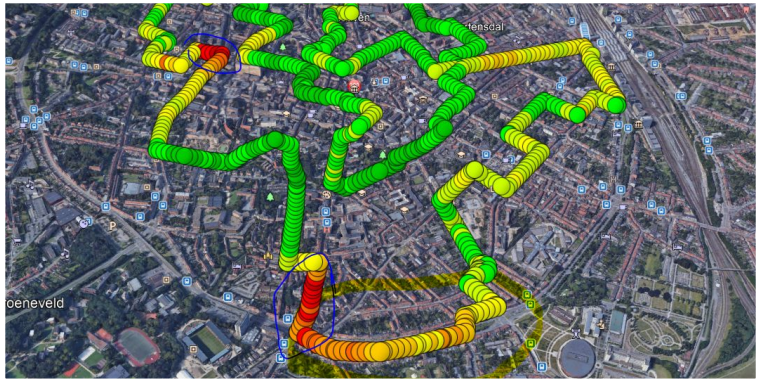
(4)

However severe air pollution can cause as serious/severe health effects as smoking, the attitude towards smoking (general accepted publicity ban and banning of smoking in public places) is far different than the attitude towards cars and wood stoves (no restrictions on publicity, as good as no restrictions on use)

Sources:
(1) https://www.tubefilter.com/2015/06/29/made-man-fiat-defy-media-big-black-bigger-is-better/ (2) http://www.alaskafireplace.com/
(3) https://www.magazine-advertisements.com/marlboro-cigarettes.html (4) Not subjected to copyright

We can reduce air pollution exposure for cyclists and pedestrians by

1. Smart-design of cycle paths, separated from traffic.
2. Reduce traffic, ban/tax cars, ban/tax wood stoves.
3. **Developing an application simulating healthiest route, encouraging people to choose a healthier route alternative.**
4. Raising awareness for causes of air pollution.
5. In general , cyclists and pedestrians are recommended to avoid as much as possible **‘city rings’** and **car-busy ‘street canyons’.**



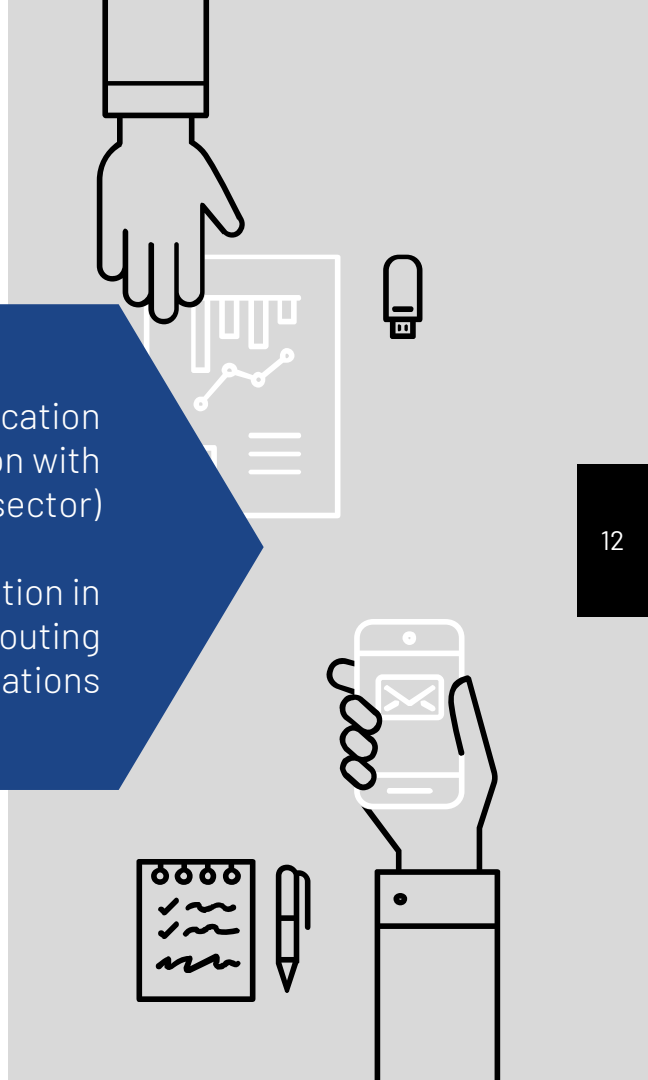
(based on data of (Leuven 2030))

Trajectory measurements of Black carbon in peak hours, May-June 2016, Leuven, Belgium

The overview of those measurements confirms that in generally, the city ring is the most polluted, with only some small exceptions, the car-busy ‘Street Canyons’ (very small streets with high buildings).

OUR PROCESS

WCS Data Exchange Model Rio-IFDM Real_Time chain API	Literature Review Data-preparation Data-Analysis Data-validation API Optimization Scientific Publication	Demo Application (in cooperation with private sector) API implementation in existing routing applications



3 “ end products”

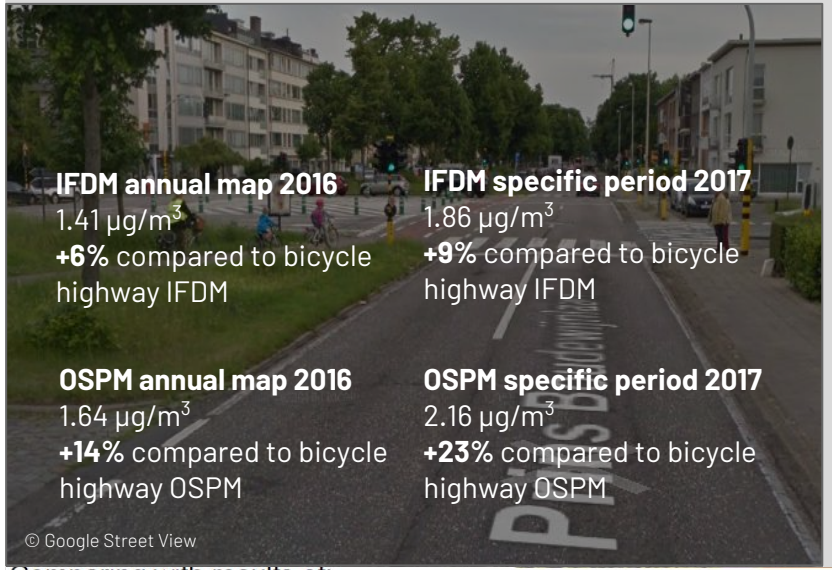
- Scientific publication
- Demo application
- Implementation of API

Research Results

Traffic Road (Antwerp, BE)

Measurements (mean): 3.38 µg/m^3

+256%vs. Bicycle highway
(measurements)



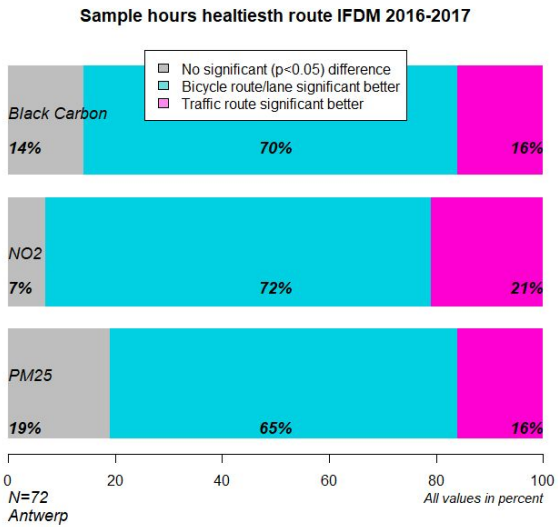
Comparing with results of:
Hofman, J. *et al.* "Cyclist exposure to black carbon, ultrafine particles and heavy metals: An experimental study along two commuting routes near Antwerp, Belgium." Environmental Research. Volume 164, July 2018, Pages 530-538

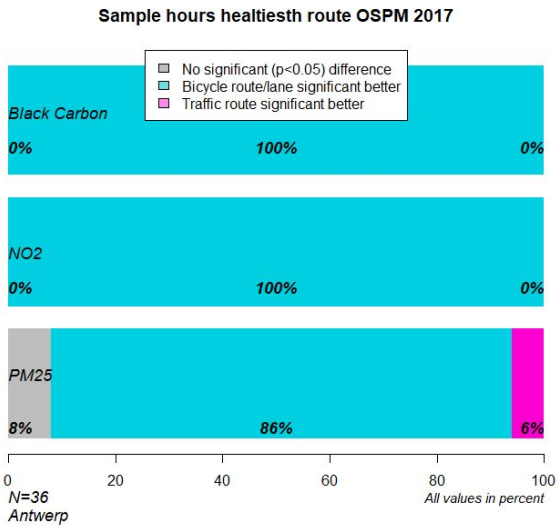
Bicycle Highway (Antwerp, BE)

Measurements (mean) 1.32 µg/m^3

Significant difference in air quality for different route alternatives ?

Based on t.test





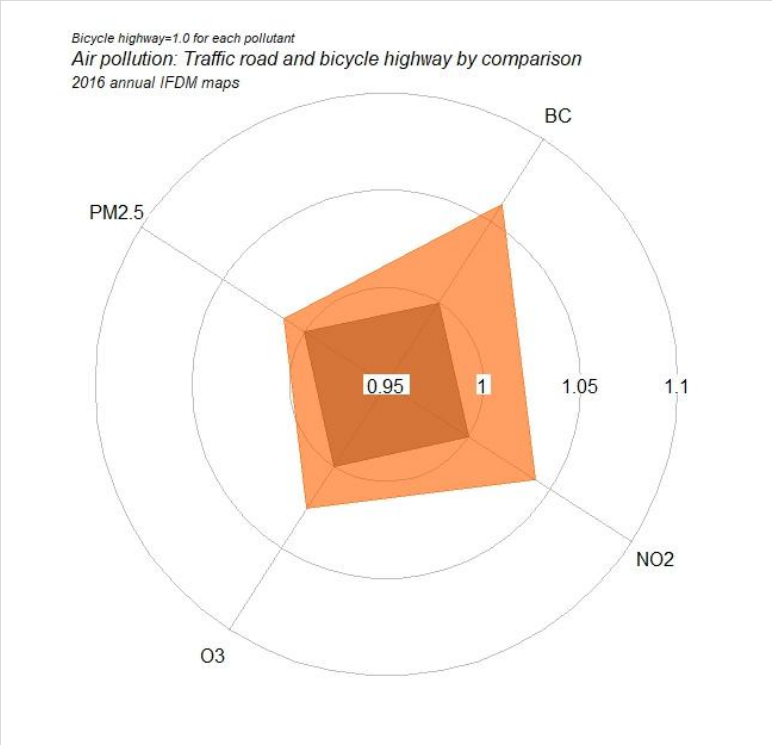
If we simulate for 72 randomly selected dates, the healthiest route at 08h, 13h and 17h, the IFDM real time chain suggests that the bicycle highway is the best choice in 70% of the cases and the traffic route 16% of the time.

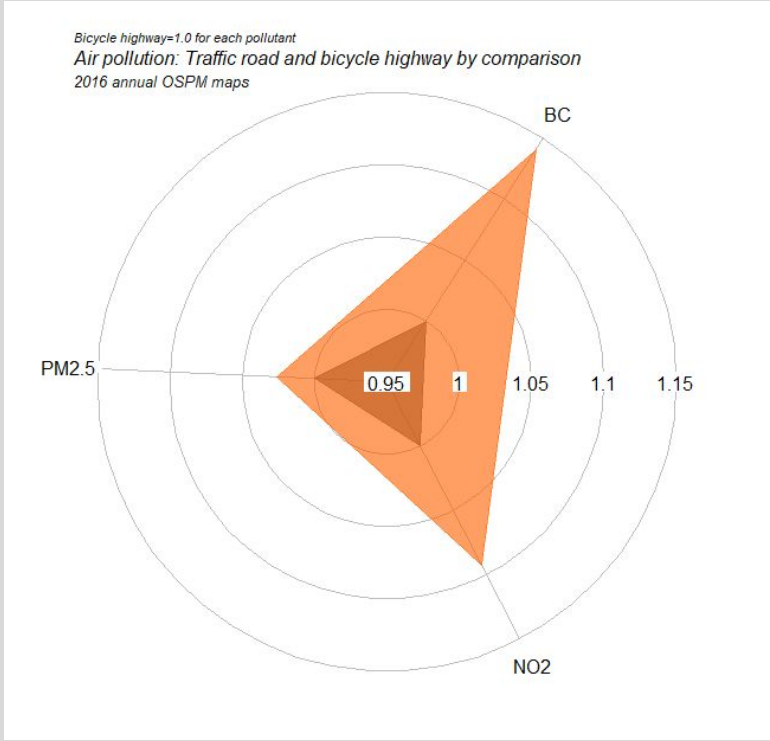
According to OSPM, the bicycle highway is better 100% of the time for BC and NO2, which is also suggested by the measurements and very likely is true.

IFDM Real Time wrongly suggests to prefer traffic road in some cases because of serious underestimation of air pollution on high-traffic roads and street canyons, and a simulated difference in air pollution between bicycle highways and traffic roads that is far below the differences of trajectory measurements.

Real Time RIO-IFDM chain not suitable to use for implementation in routing applications

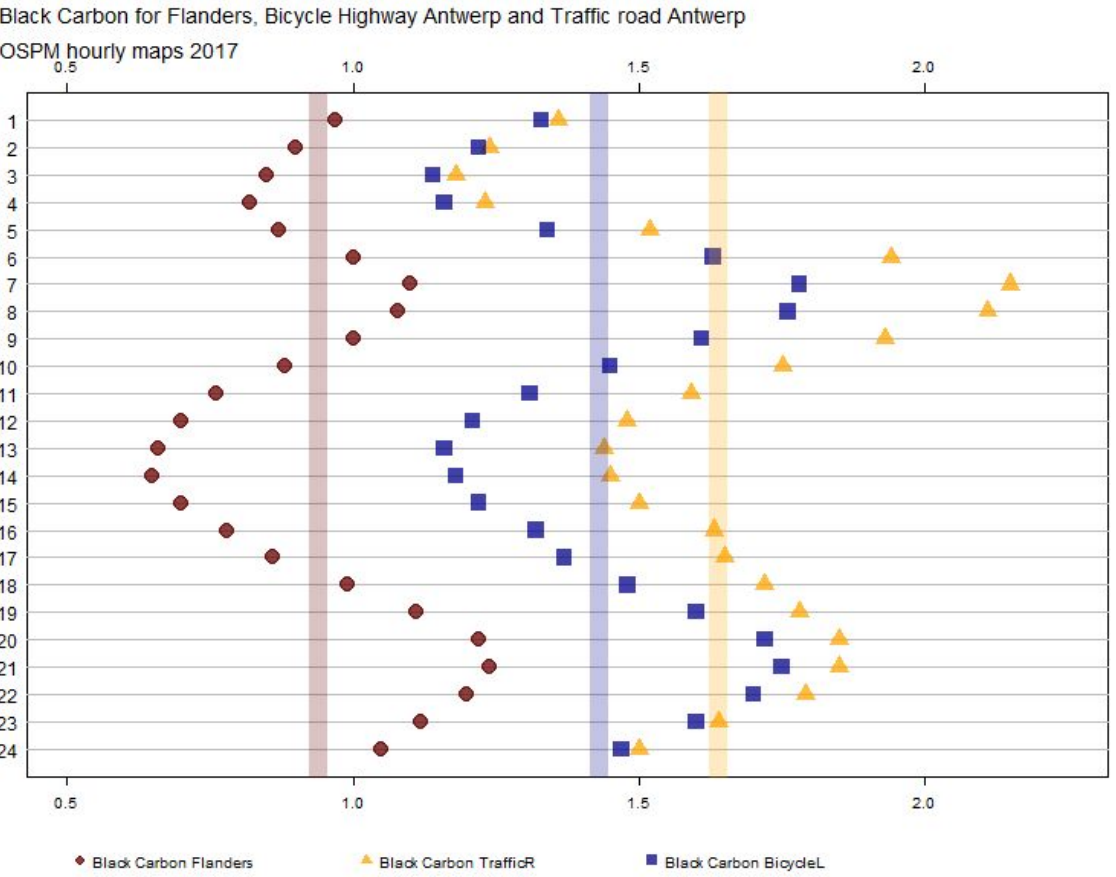
Comparison of pollutants annual model maps





Comparison with pollutants
Left: Difference for pollutants between bicycle highway and traffic road for IFDM annual map (e.g. BC : 6% difference, NO2: 4% difference)
Right: same for OSPM (Atmostreet) Map (e.g. BC: 14% difference, NO2 10% difference between traffic road and bicycle highway)

Daily pattern of air pollution concentrations (annual, 2016)



Average hourly Black Carbon (BC) concentrations for 2016 of Flanders (brown), a cycle-highway in Antwerp (blue) and a traffic-busy road in Antwerp (yellow). The vertical bars represent the daily average.

Model: OSPM-ATMOSTREET static annual hourly maps

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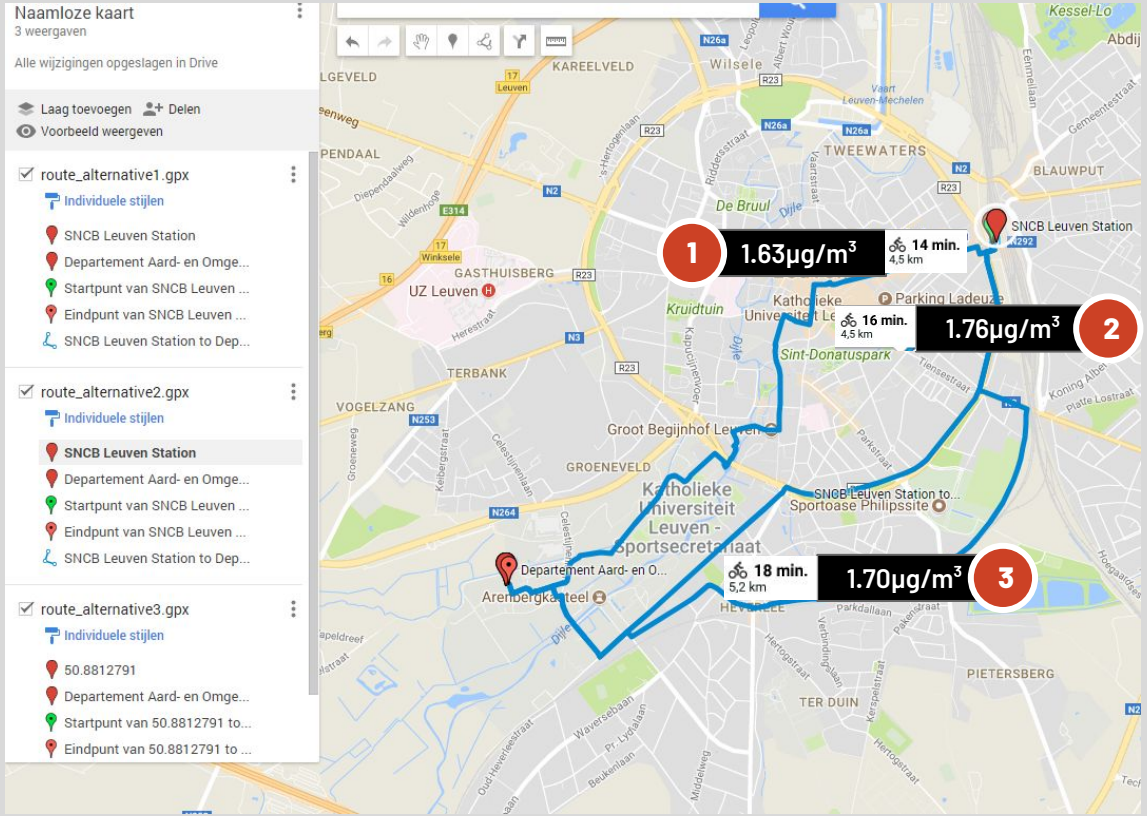
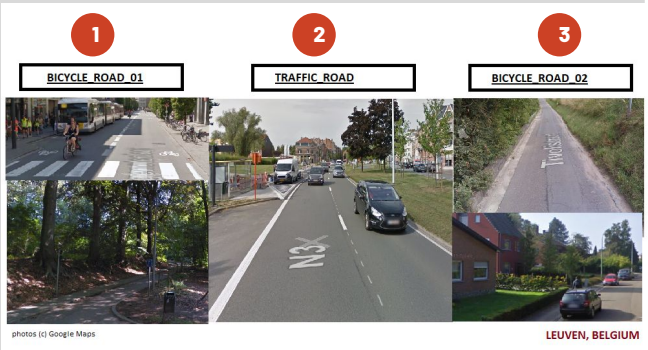
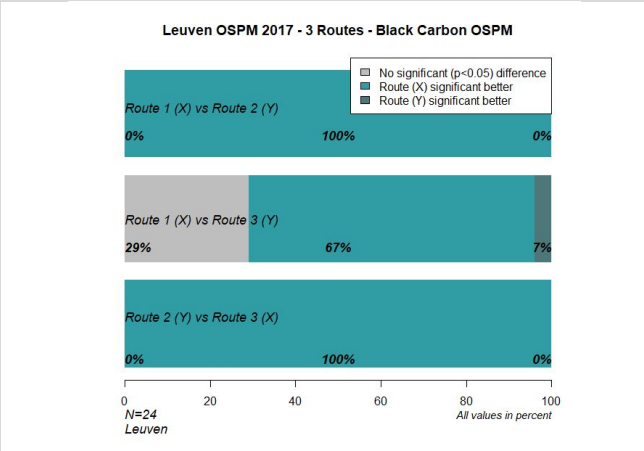
Same results if we repeat analysis for other routes at other locations (e.g. Leuven, 3 routes)



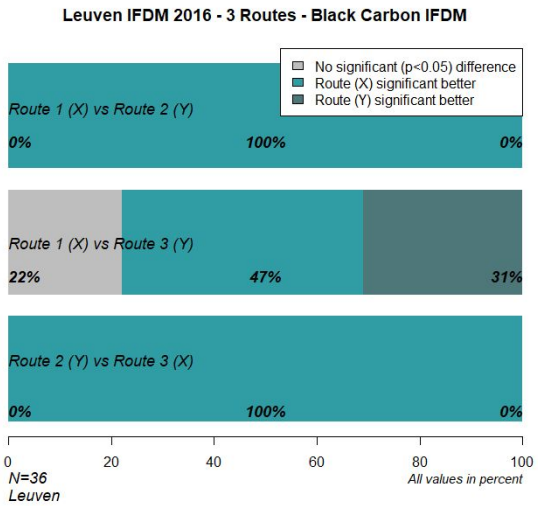


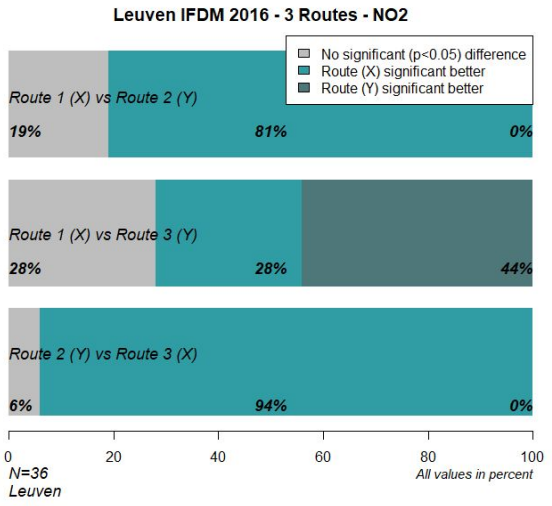


CONCLUSIONS

For similar (time, distance) route alternatives, there is in most cases a route with significant lower air pollution concentrations
BC seems to be most suitable pollutant to use

- ➔ Most correlated with traffic than other pollutants including NO2
- ➔ (somewhat) More correlated with PM 2.5 than NO2
- ➔ BC is most damaging pollutant in terms of health effects





Model Evaluation:
Overall score based on 5 measures

COE	Tells something about predictive advantage of model
R^2	Important insights in the spatial correlation between observations and model
FAC2	Tells which % of the modelled value is unacceptable far from the observation
RMSE	Overall performance measure of how close modelled values are to observed values
IOA	Average relative error, comparing model deviations with observed deviations from the mean The index of agreement can detect additive and proportional differences in the observed and simulated means and variances

Root mean squared error, *RMSE*

The RMSE is a commonly used statistic that provides a good overall measure of how close modelled values are to predicted values.

$$RMSE = \left(\frac{\sum_{i=1}^{n} (M_i - O_i)^2}{n} \right)^{1/2} \quad (22)$$

Fraction of predictions within a factor or two, *FAC2*

The fraction of modelled values within a factor of two of the observed values are the fraction of model predictions that satisfy:

$$0.5 \leq \frac{M_i}{O_i} \leq 2.0 \quad (17)$$

Correlation coefficient, *r*

The (Pearson) correlation coefficient is a measure of the strength of the linear relationship between two variables. If there is perfect linear relationship with positive slope between the two variables, $r = 1$. If there is a perfect linear relationship with negative slope between the two variables $r = -1$. A correlation coefficient of 0 means that there is no linear relationship between the variables. Note that `modStats` accepts an option `method`, which can be set to "kendall" and "spearman" for alternative calculations of *r*.

$$r = \frac{1}{(n-1)} \sum_{i=1}^{n} \left(\frac{M_i - \overline{M}}{\sigma_M} \right) \left(\frac{O_i - \overline{O}}{\sigma_O} \right) \quad (23)$$

Coefficient of Efficiency, *COE*

The *Coefficient of Efficiency* based on Legates and McCabe (2012) and Legates and McCabe Jr (1999). There have been many suggestions for measuring model performance over the years, but the *COE* is a simple formulation which is easy to interpret.

A perfect model has a *COE* = 1. As noted by Legates and McCabe although the *COE* has no lower bound, a value of *COE* = 0.0 has a fundamental meaning. It implies that the model is no more able to predict the observed values than does the observed mean. Therefore, since the model can explain no more of the variation in the observed values than can the observed mean, such a model can have no predictive advantage.

For negative values of *COE*, the model is less effective than the observed mean in predicting the variation in the observations.

Index of Agreement, *IOA*

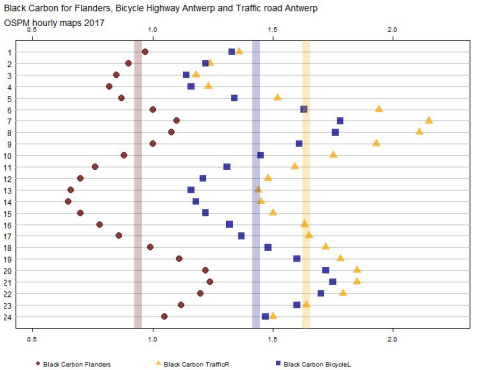
The *Index of Agreement*, *IOA* is commonly used in model eva 2011). It spans between −1 and +1 with values approaching + model performance. An *IOA* of 0.5, for example, indicates that

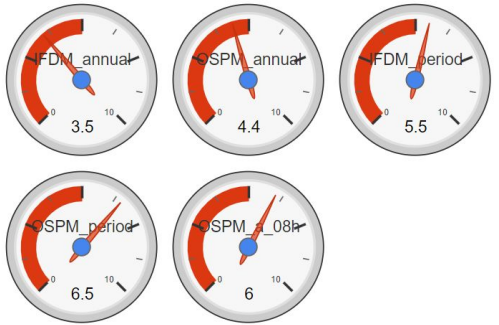
$$IOA = \begin{cases} 1.0 - \dfrac{\sum_{i=1}^{n} |M_i - O_i|}{c \sum_{i=1}^{n} |O_i - \overline{O}|}, & when \\ \dfrac{c \sum_{i=1}^{n} |O_i - \overline{O}|}{\sum_{i=1}^{n} |M_i - O_i|} - 1.0, & when \end{cases} \quad \sum_{i=1}^{n} |M_i - O_i| \leq c \sum_{i=1}^{n} |O_i - \overline{O}| \quad \sum_{i=1}^{n} |M_i - O_i| > c \sum_{i=1}^{n} |O_i - \overline{O}|$$

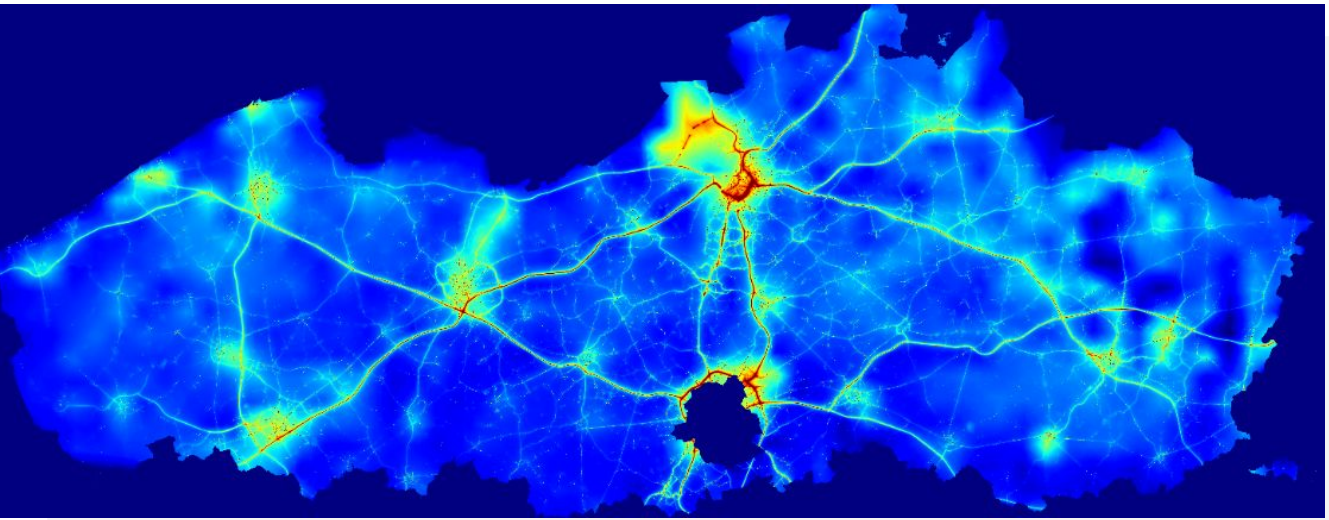
CONCLUSIONS

OSPM annual-hourly maps seem to be by far the best in terms of performance , in all cases (yearly maps of hourly air quality : OSPM 00h, 01h, 02h, 03h, ...)

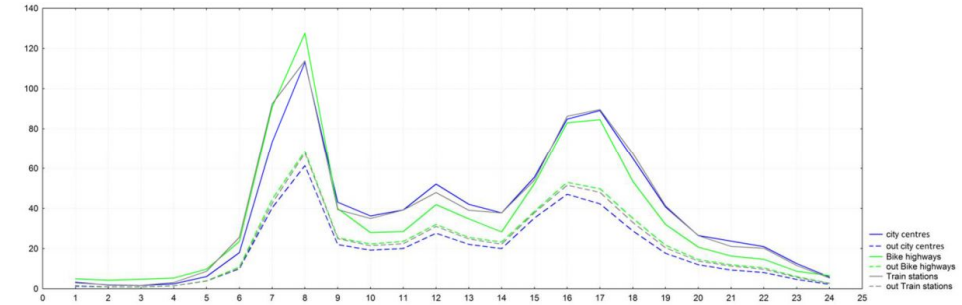
- ➔ OSPM annual maps always beat IFDM annual maps
- ➔ Real-time IFDM unsuitable (see higher), real-time OSPM not yet available



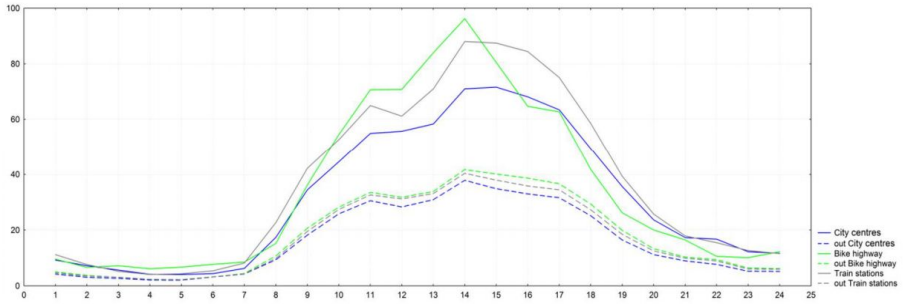




Black carbon map of flanders
Atmostreet model
Annual mean 08h



Evolution of number of cyclists on weekdays during day on counting points (fietstelweek, 2016).



Evolution of number of cyclists in weekend during day on counting points (fietstelweek, 2016)

End product 1: Scientific Publication
Scientifically sound methodology to implement air pollution data in (routing) apps

A scientifically sound methodology to include air pollution (model) data in routing applications

B. Vandeninden [1], XX[1], XX [2]

[1]Belgian Interregional Environment Agency, Brussels , Belgium
[2] XXX

Keywords: air pollution, cyclist exposure, model evaluation, routing.

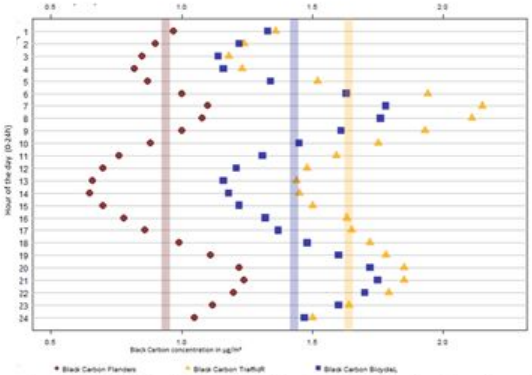
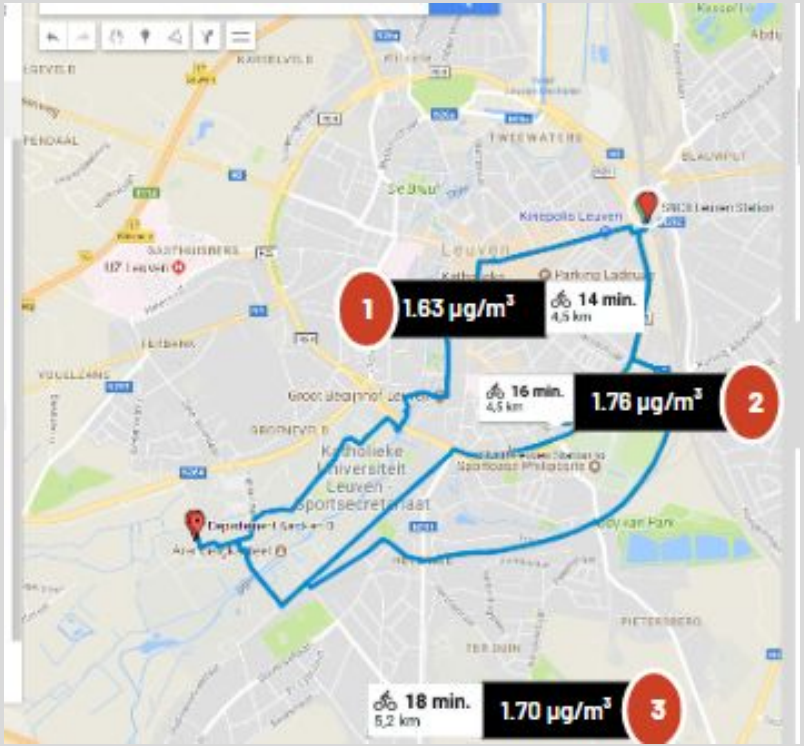


Figure 1. Average hourly Black Carbon (BC) concentrations for 2016 of Flanders (brown), a cycle-highway in Antwerp (blue) and a traffic-busy road in Antwerp (yellow). The vertical bars represent the daily average. Model: OSPM-ATMOSTREET static annual hourly maps

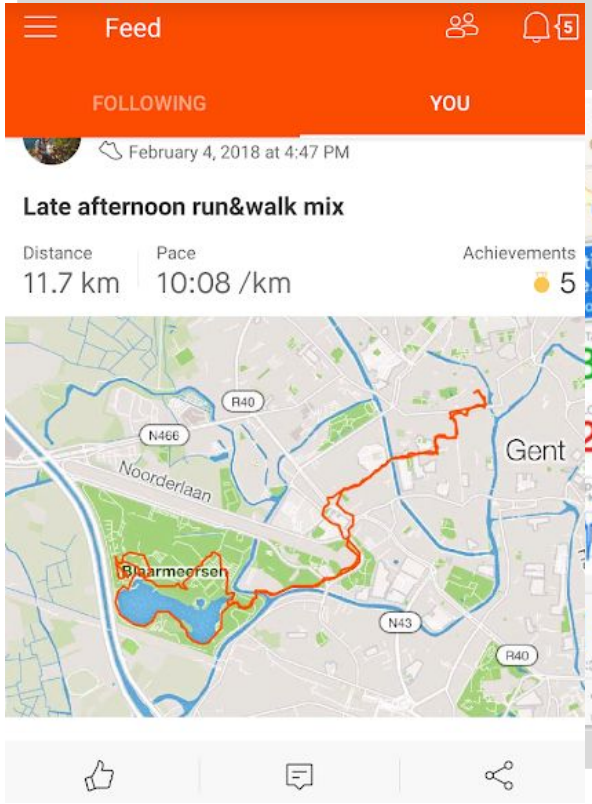
Cyclists and pedestrians often commute in polluted air without being aware of it. Due do their physical effort during travel, they inhale during travel more the air pollution compared to other transport modes (Pankow *et al,* 2014). We will provide an API that can be used to incorporate air quality in routing applications (or in seems to be the most suitable pollutant to use in such an application. To choose the best available model, we compare our best available air quality models with trajectory measurements of Black Carbon in the Antwerp, Leuven and Mechelen area. The real-time chain of the high-resolution IFDM model is unsuitable to

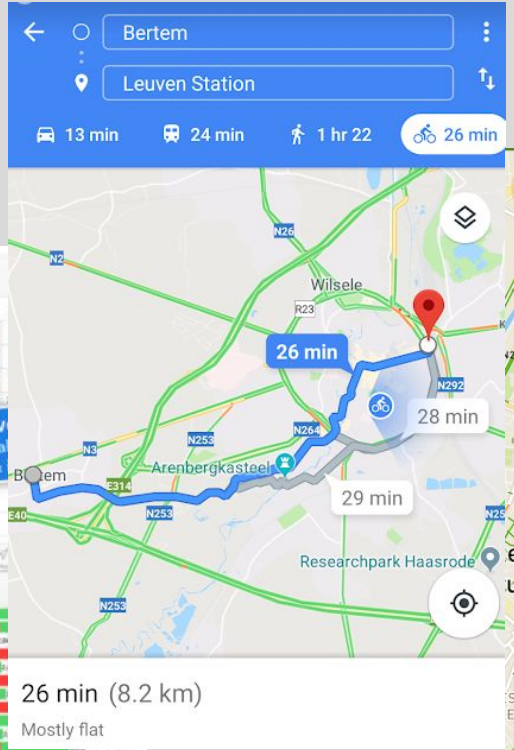
End product 2: Demo application

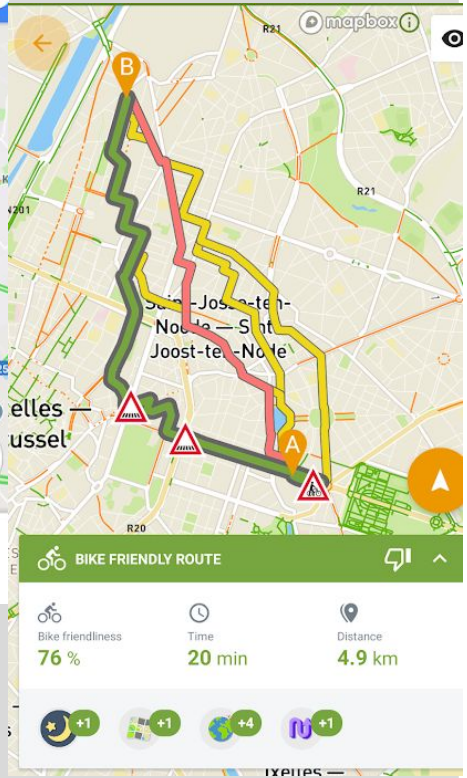


Cooperation with existing routing planner or new app based on existing routing API

End product 3: Implementation of API in many different routing apps and recreational apps (?)







Applications based on our API:

Only for pedestrians and cyclists, not for cars!!!

Value proposition

Financial benefits for the company (1)

- ➔ Advertising
- ➔ Money from customers (e.g. free version with ads, pay version without ads, but same content)
- ➔ Initial funding from Be-GOOD project (only demo-application)

Quality label, permanent quality control (4)

- ➔ Cooperation with IRCEL-CELINE guarantees permanent quality control
- ➔ Cooperation with IRCEL-CELINE provides a kind of 'quality label' to the designed application

Societal benefits (2)

- ➔ Reduced Health Care costs, increased productivity, ...
- ➔ (possibly) increased traffic safety, reduction of traffic casualties (indirectly people are suggested to take route with fewer cars)
- ➔ Acquisition of knowledge

Benefits for individuals (4)

- ➔ Health benefits: less respiratory problems, less strokes (cardiovascular attacks) (short term), reduced cancer risk (long term)

Sources: (2) https://www.rydoze.com/cycling-benefits