FAT Forschungsvereinigung Automobiltechnik

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The Contribution of Brake Wear Emissions to Particulate Matter in Ambient Air

Dan Wakeling

Dr David Carslaw, Dr Tim Murrells, Dr John Norris

Project for the German Research Association of Automotive Technology (FAT)

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Overview of this presentation

- **Overview of the client and project team**
- **Summary of the three project tasks:**
  - **Task 1**
    - Critical review of the scientific literature on the contribution of brake wear, and other traffic-related sources, to ambient concentrations of PM
  - **Task 2**
    - Brake wear contributions according to national emissions inventories
  - **Task 3**
    - Scoping study into how uncertainties in brake wear emission estimates, and their contribution to PM air pollution, can be reduced
    - Brake wear emissions from modern vehicle technologies
- **Current work**

Overview of the client and the project team

- **Client:** The Research Association of Automotive Technology (FAT)
  - The FAT unites all German passenger and commercial vehicle manufacturers as well as numerous suppliers under the auspices of the Verband der Automobiliindustrie (VDA), for the purpose of carrying out pre-competitive joint research
  - The VDA is an interest group of the German automobile industry

- **Project team:** Ricardo Energy & Environment (Division of Ricardo)
  - Environmental consultancy and air quality specialist
  - Core project team:
    - Dr David Carslaw (affiliated with University of York) – expert on analysis of air quality data and source apportionment
    - Dr Tim Murrells – expert in emission inventories and transport emissions modelling
    - Dr John Norris – expert in vehicle emissions and powertrains
    - Dan Wakeling – specialist on emissions data analysis

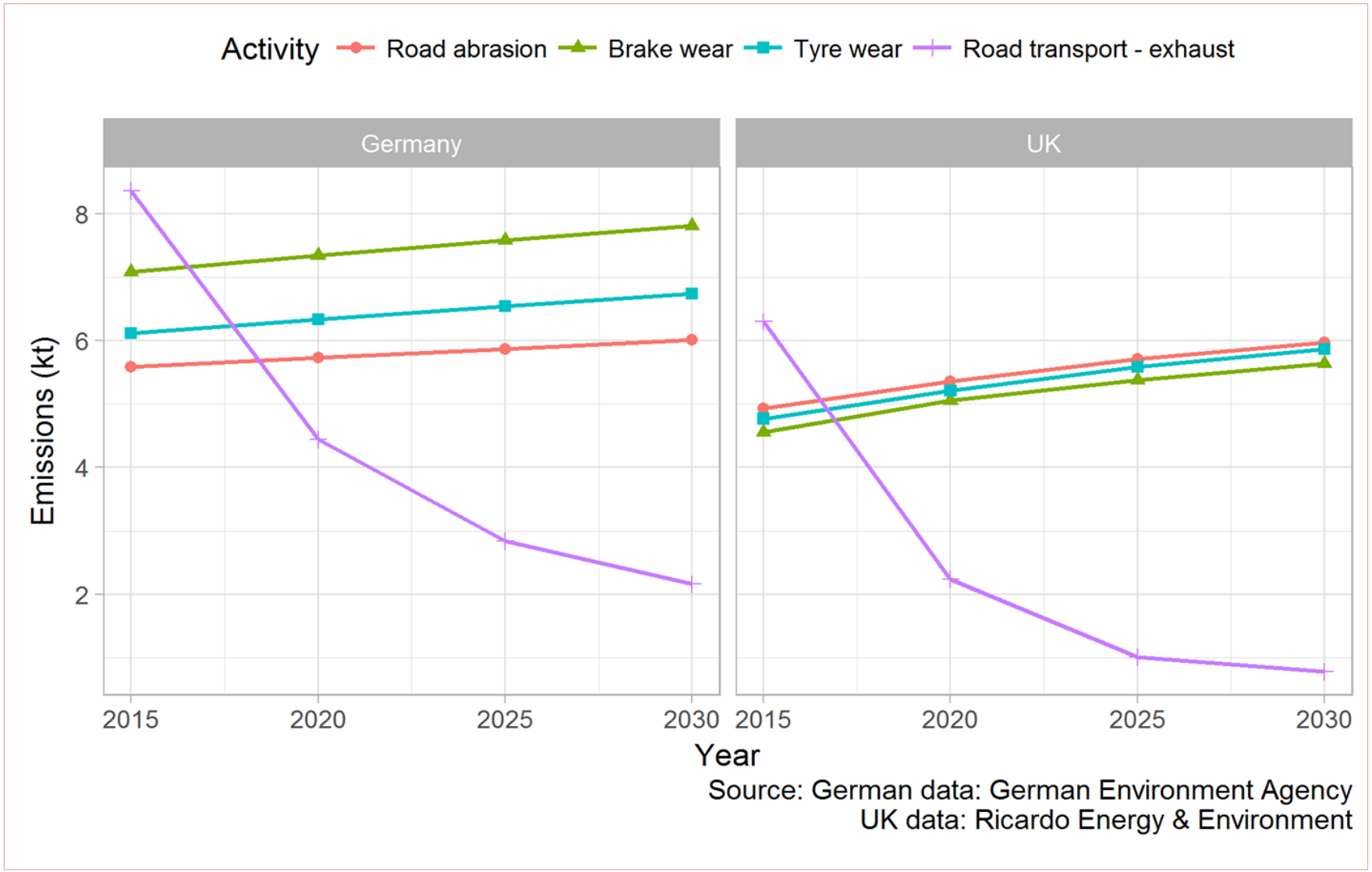
Task 1 – Scientific literature review

The contribution of brake wear to ambient PM concentrations

- Very few articles explicitly provided a quantitative estimate of the contribution of brake wear to ambient PM concentrations.
- Around **5-10% of PM_{10} concentrations in busy urban roadside areas** (~0.8 μg m^{-3} to 4 μg m^{-3})
- The contribution of brake wear to ambient PM concentrations is highly spatially and temporally variable.
- Articles cite considerable **uncertainties**:
  - "*there is a clear lack of data in the field of road transport wear (…) emissions to conclusively assess its importance for air quality and the impact on human health*" (Denier van der Gon et al. (2013))
  - "*quantitative knowledge of the contribution, especially of non-exhaust emissions to PM concentrations remain inadequate*" (Pant & Harrison, 2013)

Task 2 – Analysis of National Emissions Inventory data

- UK and German PM_{10} emissions from road transport sources



The scale on the y-axis applies to both countries.

Task 3 – Scoping study

How uncertainties in brake wear emission estimates can be reduced

- Emissions inventories don't account for the high spatial variability of emissions.
- In principle, it is possible to produce a better estimate of where brakes are used i.e. a '**brake use inventory**'.
- This would identify the conditions under which brakes are applied together with an estimate of the energy dissipation in doing so.
- The development of a brake use inventory could:
  - help identify locations where brake wear emissions would tend to be highest.
  - have direct relevance for understanding the optimum location for making ambient measurements aimed at quantifying brake wear emissions of PM.

Modelling approach

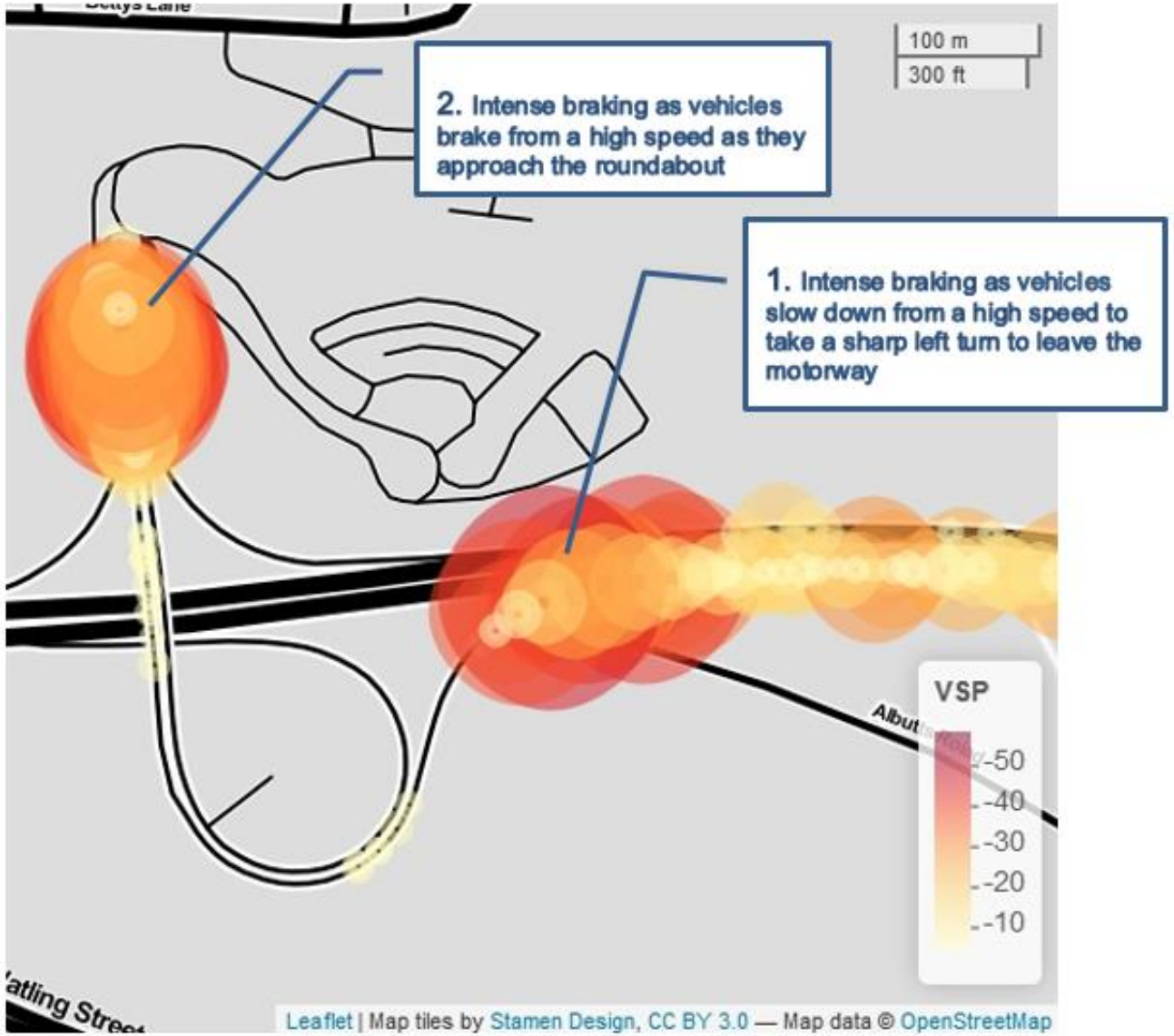
- Analysis of high resolution data from on-road measurements of real vehicles
- Location, speed, and altitude, amongst other metrics, of 19 passenger cars tested along urban, rural, and motorway roads in central England
- Data processed to provide an estimate of the second by second Vehicle Specific Power (VSP). VSP is a mathematical representation of the engine load required to overcome aerodynamic drag, acceleration, rolling resistance, plus the kinetic and potential energies of the vehicle, all divided by the mass of the vehicle
  - Considered as a proxy for brake use

Simplified representation of the data applied

time	lat	lon	speed	mass	VSP
0	52.60000	1.70000	0	1500	0
1	52.60002	1.70001	5	1500	10
2	52.60004	1.70002	10	1500	30
3	52.60006	1.70003	5	1500	-30
4	52.60008	1.70004	0	1500	-10

Task 3 – Scoping study

- **VSP (VSP < -5 kW/t) at a motorway exit road**



Source: Ricardo Energy & Environment – using UK Department for Transport research data

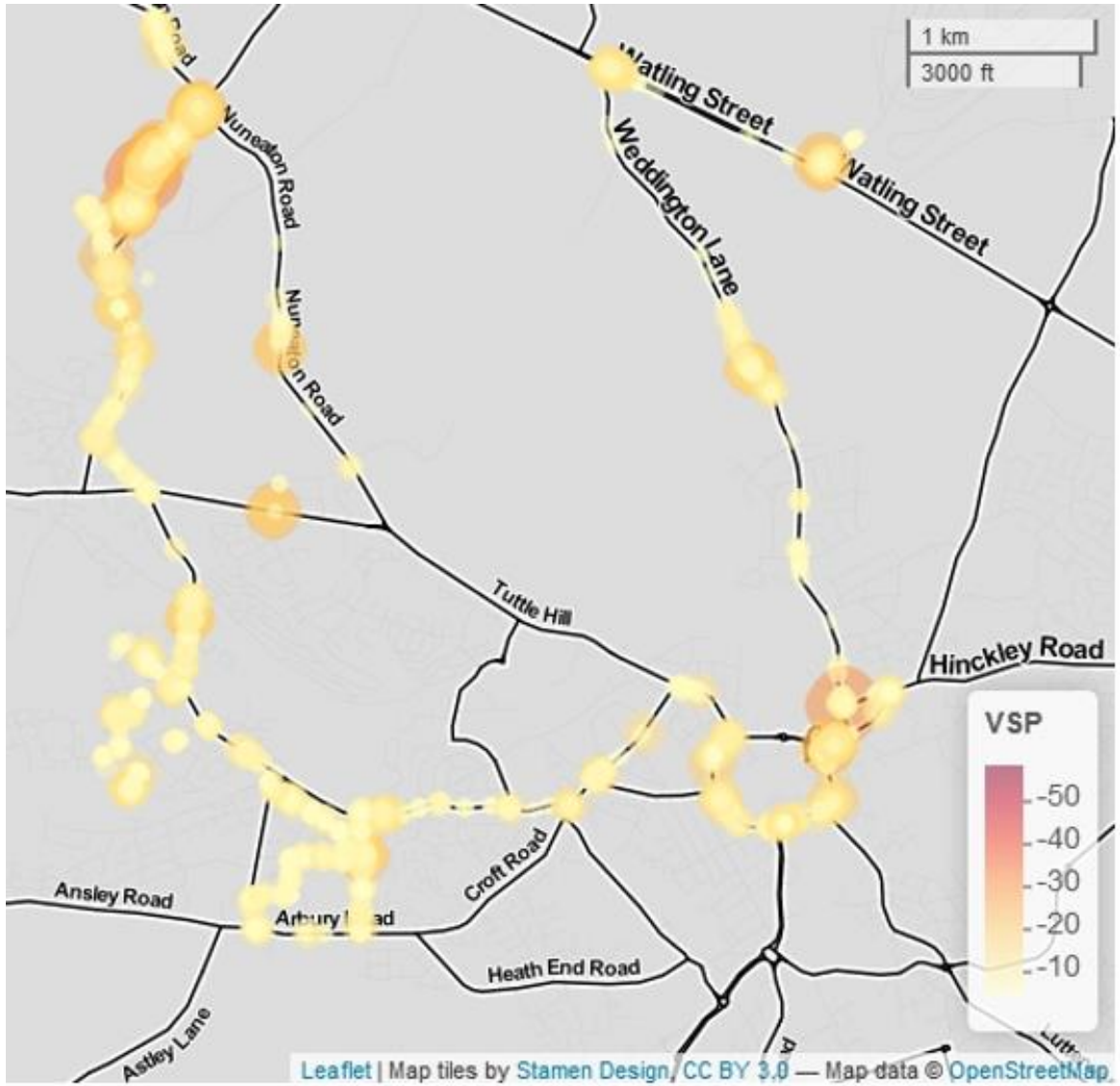
Task 3 – Scoping study

- **Slip/exit road from motorway**

Image source:
Google Maps – May 23 2017

Task 3 – Scoping study

- **VSP (VSP < -5 kW/t) in the town of Nuneaton**



Source:
Ricardo Energy & Environment – using UK Department for Transport research data

Emissions for future vehicle and brake technologies

Potential change	Passenger cars	Light commercial vehicles	Rigid lorries	Articulated lorries	Buses and coaches
System specification – light-weighting	1	1	2	2	2
Carbon ceramic discs	2	0	0	0	0
Regenerative braking	5	4	2	1	4
Positive piston retraction	1	1	1	1	1
Brake-by-wire	2	2	2	2	2

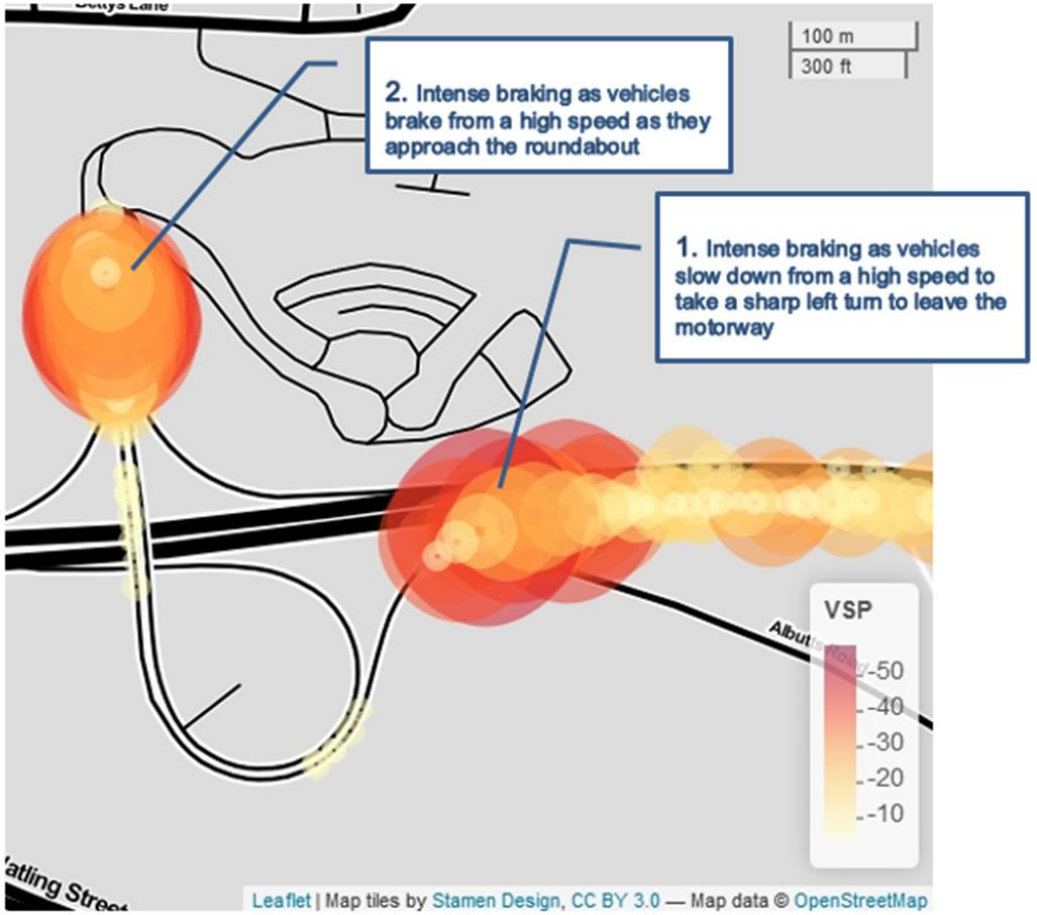
Current work – impacts on air quality through modelling

- Develop a brake use inventory that can better reflect the actual distribution of brake wear emissions
- Understand the impacts on air quality through modelling
- There are three main tasks:
  - [1] Develop a brake use inventory
  - [2] Brake wear emission estimates
  - [3] Air quality modelling

Current work

Work package [1]: Develop spatial-temporal brake use inventory

- Use comprehensive vehicle activity data to determine when and to what extent brakes are used
- Base on estimated vehicle energy dissipation (from data on vehicle mass, speed, acceleration, road gradient)
- Data sets such as euroFOT record actual brake use
- Will yield a spatial-temporal inventory of where brakes are used and the strength of braking



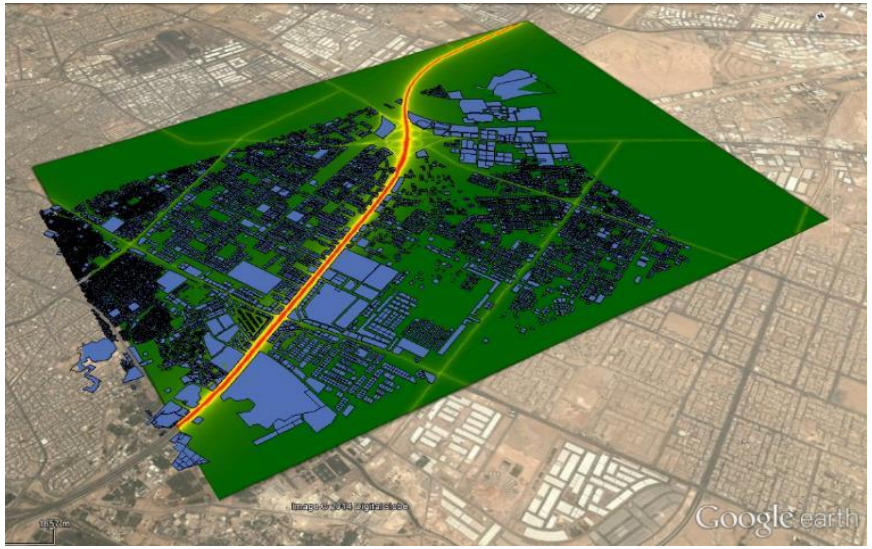
Work package [2]: Brake wear emission estimates

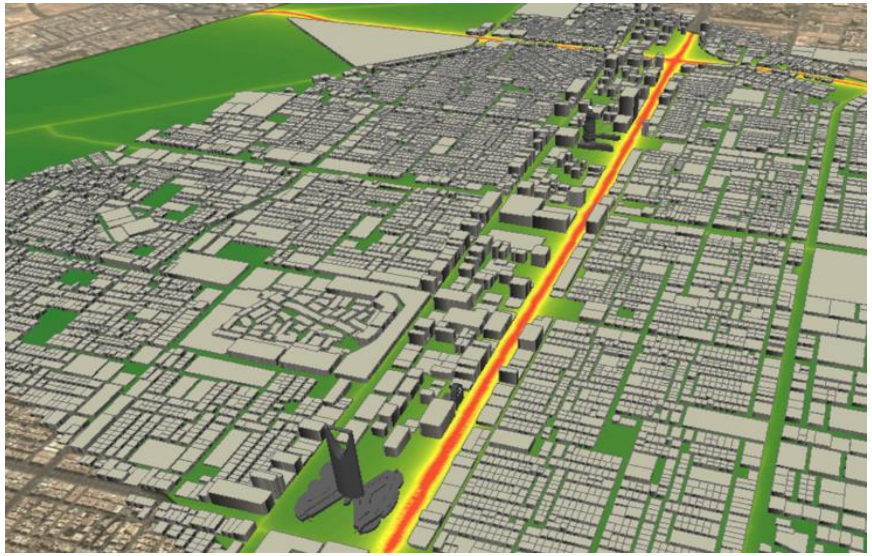
- Review brake wear emission factors and apportion to new inventory
- Output will be a spatially and temporally resolved brake wear emissions inventory

Current work

Work package [3]: Air quality model predictions

- Main aim to determine the likely effect on particulate matter (PM_{10}) concentrations
- Use the Ricardo *RapidAir* model – advanced Gaussian model, developed for urban air quality modelling
  - Considers local meteorological data
- Will answer questions such as:
  - Effect of using new brake wear inventory
  - Location types with minimum and maximum impacts
  - Source apportionment – how much do brake wear emissions contribute to overall concentrations?
  - Implications for urban air quality





Concluding remarks

- Measurements to understand the contribution of brake wear are highly uncertain and variable
- Inventories show that non-exhaust emissions sources are now starting to become relatively more important than exhaust emissions sources; a new era
- We have developed an approach using real vehicle activity data to produce a high resolution brake use inventory
- We are developing a more refined high resolution brake use inventory, to combine with contemporary emissions estimates, to understand the impacts on air quality through modelling

Contact details

Dan Wakeling

Senior Consultant – Ricardo Energy & Environment

Environmental consultancy and air quality specialist

daniel.wakeling@ricardo.com