Institution: King's College London		
Unit of Assessment: UoA2		
Title of case study: Underpinning Evidence for Traffic Control Schemes in the UK and Internationally to Improve Air Quality and Health		
Period when the underpinning research was undertaken: 2014 – 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Frank Kelly	Professor	2000 – 2020
Martin Williams	Professor	2000 – 2020
Sean Beevers	Reader	2000 – 2020
Ian Mudway	Senior Lecturer	2000 – 2020
Benjamin Barratt	Senior Lecturer	2000 – 2020
Gary Fuller	Senior Lecturer	2000 – 2020
Stephanie Wright	Research Fellow	2016 – 2020
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

King's research, based on the London Air Quality Network (LAQN), provided the scientific foundation for a series of environmental policies to improve air quality in London. This included the Congestion Charging scheme and the Low Emission Zone (LEZ), which were in force throughout the assessment period, and the Ultra Low Emission Zone (ULEZ) from 2019 onwards. King's provided detailed assessments of air pollution impacts of policy options, allowing the selection and design of the most effective strategies to tackle air pollution in London. The research also quantified the health impacts of air pollution, helping to drive public support for more ambitious policies. This has increased international interest in these methods of pollution control resulting in the adoption of similar interventions across Europe and world-wide.

2. Underpinning research

Poor air quality is an important public health issue especially in cities where traffic is the major source of pollution. It is estimated that 3.4 million people die prematurely across the world each year (1.3 million in China, 110,000 in the US and 400,000 in Europe), because of outdoor air pollution.

Research by King's quantifies the impacts of air pollutants on health. Established in 2009, in partnership with three other universities, King's College London's Medical Research Council (MRC) Centre for Environment and Health was a leading centre for research on air quality and health during the assessment period. King's established and maintained the London Air Quality Network (LAQN) from 1995 to 2020 (when the group moved to Imperial College), and this evolved into the largest urban air quality network in Europe, consisting of over 120 fixed measurement sites for a range of pollutants. King's research from 2000 onwards used information from the LAQN to understand the sources of atmospheric pollution and to estimate the health impacts of these pollutants. In cities, vehicles are the main contributors to air pollution. King's research showed that emissions include strong oxidants which damage the delicate respiratory airways, decreasing airway function and causing inflammation. This provided evidence that exposure to transport-related pollutants is a cause of ill health.

King's scientists design and evaluate interventions to reduce harmful exposures. The King's team conducted research to support the design of traffic control schemes and contribute to their evaluation in order to improve air quality and, hence, health **(1, 2)**. King's developed an air pollution model **(3)** that provided highly detailed road-by-road traffic emissions estimates **(2, 4, 5)**.

King's traffic emissions models are now included in the London Atmospheric Emissions Inventory and are used for all air pollution and climate change projects in London.

Working in partnership with Transport for London, King's modelling quantified the expected air quality impact of the introduction of a congestion charging scheme (CCS). King's research suggested that the health benefits of the CCS introduction might be small and so began to determine the potential benefit of introducing a London-wide low emission zone (LEZ). Prior to activation of the first phase of the LEZ in 2008, King's research showed that a LEZ could provide improvements in urban air quality, crucially predicting that the emissions controls enforced by the scheme were expected to have the greatest effect close to major roads with high volumes of heavy-goods-vehicle traffic. Research led by King's quantified the impact of the LEZ on the respiratory health of school children **(6)**. King's researchers were also instrumental in highlighting the acute health responses of pedestrians exposed to traffic pollution in London **(7)**, supporting evidence for further tightening of emissions controls via the subsequent ULEZ.

King's research linked air pollution to a number of public health issues.. Air pollution data can be combined with public health data to examine correlations with disease. Between 2014 and 2019, the King's model has been linked to hospital episodes data (HES), primary care electronic health records (CPRD), census, cohort and registry data in multiple research publications to investigate associations with cardiovascular, respiratory, cognitive, neurological, perinatal and post-natal morbidity and mortality. The King's model is also being developed to track individual exposure to air pollution **(4)**.

3. References to the research

(1) Beevers, S. D., Carslaw, D. C., Dajnak, D., Stewart, G. B., **Williams, M. L.**, Fussell, J et al. Traffic management strategies for emissions reduction: recent experience in London. *Energy and Emission Control Technologies.* 2016;**4**: 27-39. doi: 10.2147/EECT.S69858

(2) Beevers, S. D., Westmoreland, E., De Jong, M., **Williams, M. L.** & Carslaw, D. C. Trends in NOx and NO2 emissions from road traffic in Great Britain. *Atmos Environ* 2012: **54:** 107-116. doi: 10.1016/j.atmosenv.2012.02.028

(3) Smith JD, Mitsakou C, Kitwiroon N, **Barratt BM**, Walton HA, Taylor JG et al. London Hybrid Exposure Model: Improving Human Exposure Estimates to NO(2) and PM(2.5) in an Urban Setting. *Environ Sci Technol*. 2016;**50**(21):11760-11768. doi: 10.1021/acs.est.6b01817.

(4) Beevers SD, Kitwiroon N, **Williams ML**, **Kelly FJ**, Ross Anderson H, Carslaw DC. Air pollution dispersion models for human exposure predictions in London. *J Expo Sci Environ Epidemiol*. 2013;**23**(6):647-53. doi: 10.1038/jes.2013.6.

(5) Beevers SD, Kitwiroon N, **Williams ML**, Carslaw DC. One way coupling of CMAQ and a road source dispersion model for fine scale air pollution predictions. *Atmos Environ (1994).* 2012;**59**(C):47-58. doi: 10.1016/j.atmosenv.2012.05.034

(6) Mudway IS, Dundas I, Wood HE, Marlin N, Jamaludin JB, Bremner SA et al. Impact of London's low emission zone on air quality and children's respiratory health: a sequential annual cross-sectional study. *Lancet Public Health.* 2019;**4**(1):e28-e40. doi: 10.1016/S2468-2667(18)30202-0.

(7) Sinharay R, Gong J, **Barratt B**, Ohman-Strickland P, Ernst S, **Kelly FJ**, et al. Respiratory and cardiovascular responses to walking down a traffic-polluted road compared with walking in a traffic-free area in participants aged 60 years and older with chronic lung or heart disease and age-matched healthy controls: a randomised, crossover study. *Lancet.* 2018;**391**(10118):339-349. doi: 10.1016/S0140-6736(17)32643-0.

4. Details of the impact

King's air quality research had impact from 2013 to 2020 by contributing to the design, implementation and evaluation of traffic control schemes in the UK, including impact on air quality and health outcomes, and providing scientific advice on air quality to inform the development of schemes internationally. The ultimate beneficiaries from the research include the populations of urban centres world-wide, especially the most heavily exposed in deprived areas, that have directly benefited from control measures directed at reducing traffic-related air pollution. King's

research has directly benefitted and influenced stakeholders in transport policy nationally and internationally including politicians, policy-makers, planners and managers, as well as service users.

King's research influences air quality strategy in London. In 2018, the Mayor of London published the London Environment Strategy (LES) **(A)**, setting out details of policy actions to improve the city's air quality and the health and wellbeing of its residents. King's research was used in the LES to assess the impacts on pollutant concentrations of a range of policies including the new Ultra Low Emissions Zone (ULEZ) **(B)**. King's research calculated both the traffic emissions and air quality predictions of policy interventions from 2013 onwards and to future years to 2030. The LES includes plans for the London Taxi and Bus strategies, the Central London ULEZ, the London Wide HGV/Bus strategy, and the Inner London ULEZ zone for the area bounded by the North and South Circular roads **(A)**.

The underpinning research from King's led to the ambitious ULEZ. As with the preceding LEZ, King's LAQN provided data to underpin the strategy through the monitoring of air quality and emissions. The LAQN index, developed by King's, is used throughout the London Mayor's report to 'provide a picture of the overall improvements in London's air quality' **(A.1)**. The London Air Quality Network web-site not only informs Transport for London, but can be used by the public to find interactive street-level current pollution maps; incidences of high pollution episodes; interactive graphs by London borough and yearly reports. This innovative research, linked to policy, has informed the development of similar schemes throughout the UK, such as the Breathe London network, which can be used to highlight potential air quality hotspots, allowing solutions to be put in place as quickly as possible **(C.1)**. Internationally this work was propagated via the C40 Cities new Air Quality Network launched in 2018. It focused on helping cities develop and implement air quality policies and solutions to reduce air pollution, improve public health and meet climate goals **(C.2)**. The team running the LAQN was assigned 'essential worker' status during the COVID-19 pandemic and maintained the flow of essential information to the public and government agencies **(D.1)**. This service was acknowledged in writing by the Mayor of London **(D.2)**: *"The data collected through the air quality monitoring network is extremely important to the ongoing evaluation of risk during the COVID-19 pandemic. This is especially true in light of the emerging evidence of an association between exposure to air pollution and the most severe effects of COVID-19. The research your team submitted as part of the Air Quality Expert Group call for evidence shed valuable light on the immediate impact of the lockdown on London's air quality (…) Over the years you and the team have contributed hugely to our understanding of the impact air pollution is having on the health of Londoners".*

King's academics provide expert advice and advocacy to UK policy-makers. This work was extended in 2016, in collaboration with Policy Exchange, a leading think tank based in London. It resulted in two reports on air pollution in London that considered the moral, legal and economic case for doing more to tackle air pollution. The reports showed that despite the growing focus on the issue in recent years, current and planned policies are unlikely to deliver compliance with air quality limits in London until at least 2025. The reports outline the health and economic benefits of taking further steps to tackle air pollution **(E.1, E.2)**. The work tested additional policy scenarios policies with European, UK and London-wide scales. Model predictions covered future years (2020/5) and included testing the impacts of tightening enforcement of Euro 6 vehicle emission controls, reversing the diesel/petrol mix, reducing diesel numbers, increasing diesel taxation, introducing a diesel scrappage scheme, applying the ULEZ scheme including the taxi and bus strategies, encouraging electric and hybrid electric vehicles, tackling high emitting boilers and reducing the impact of new Combined Heat and Power (CHP) boilers. **(E. 2)** A ten-point plan was produced and was used as evidence at the London Assembly Environment Committee on compliance with legal air quality standards **(E.3)**. The Department for the Environment and Rural Affairs (Defra) commissioned a similar policy assessment for the whole of the UK forward to 2050, which informed the UK Government's Clean Air Strategy 2018 **(F)**, including climate change policies. A key recommendation introduced by this strategy was a new commitment to progressively cut public exposure to particulate matter pollution, halving the population living in areas with concentrations of fine particulate matter above WHO guideline levels (10 µg/m3) by 2025 **(F, Chapter 2, p.4)**.

In 2019, Professor Martin Williams was appointed as the UK's first Clean Air Champion (shared role) to spearhead the Clean Air Programme, which aims to develop solutions towards a cleaner economy **(G)**. Professor Frank Kelly gave expert advice to the European Respiratory Society Environment & Health Committee in 2019 **(H.1)** and the Future Cites Catapult in 2018 **(H.2)**, as well as evidence to the House of Commons Environmental Audit Committee in 2016 **(I)**. King's researchers have also compiled reports for DEFRA and other Government agencies including a review of air quality modelling **(J)**. Multiple local authorities in the UK are now planning and implementing LEZs including Bath, Birmingham, Bristol, Bradford, Greater Manchester, Leicester, Newcastle, Oxford, Portsmouth and Sheffield. This activity is also reflected by King's researchers' memberships of several important and influential government groups, such as the Committee on the Medical Effects of Air Pollutants, the expert advisory group of the Department of Health in the UK for which Kelly has been Chair (2011-2020) **(K.1)**; Quantification of air pollution health effects, a sub-group of COMEAP (2017-2020) **(K.2)**; and the Air Quality Expert Group, the DEFRA advisory group (2013-2020) **(K.3)**.

King's scientists provide expert advice to international agencies. King's expertise in air quality management and linking air pollution with health outcomes is widely recognised on the International stage. King's collaborated with international researchers to provide expert advice to policy makers in Paris, Beijing and Hong Kong **(L)**. King's researchers have played significant roles in the air quality review process initiated by the WHO; in 2015, Professor Williams gave expert advice and co-chaired a WHO expert consultation meeting on the future update of the WHO Global Air Quality Guidelines **(M)**. This eventually led him to co-chair the WHO Air Quality Guidelines Development Group in 2018 **(M)**. The consultation identified 32 ambient air pollutants that can pose health hazards to human populations and should be carefully followed by WHO and monitored by countries worldwide, but there was consensus that immediate priorities were particulate matter (PM), ozone (O3), nitrogen dioxide (NO2), sulphur dioxide (SO2), and carbon monoxide (CO)' **(M, pp27-8)**. King's staff were also members and consultants of influential national and international scientific panels including: the UN Economic Commission for Europe Convention on Long Range Transboundary Air Pollution (2018) **(N.1)**; and the US Health Effects Institute Review Board and their investigation into the Health Effects of Traffic pollution (2018) **(N.2)**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

(A) London Environment Strategy: A.1 Draft for Public Consultation, 2017 - Mayor of London [pages 44, 45, 52, 53] [PDF] **A.2** Executive Summary, 2018 - Mayor of London [PDF]

(B) Sources that corroborate King's research influencing ULEZ: B.1 Ultra Low Emission Zone consultation - Supplementary information: Mayor of London, Transport for London. 2014, [page 82] [PDF]; **B.2** Proposals to improve air quality - Report to the Mayor on consultation: APPENDIX B List of Stakeholders invited to respond, 2017 [page 5] [PDF]

(C) Sources that corroborate King's research informing the development of similar air quality network schemes throughout the UK: C.1 Press Release from Mayor of London Website: 'Mayor publishes first data from Breathe London network' 2019; **C.2** Press Release from C40 Cities Website 'Mayor launches world's largest air quality monitoring network in London'

(D) Sources that corroborate LAQN's importance during the COVID-19 pandemic: D.1 Air Quality Expert Group. Annex to the AQEG report - submissions cited in the published work: Estimation of changes in air pollution emissions, concentrations and exposure during the COVID-19 outbreak in the UK. Rapid evidence review, 2020 [page 64] [PDF]; **D.2** Testimonial from The Mayor of London [PDF]

(E) Sources that corroborate claim of King's researchers providing expert advice and advocacy to UK policy-makers: E.1 UP IN THE AIR - How to Solve London's Air Quality Crisis: Part 1, 2016 [pages 4, 6, 9, 13, 16, 20, 35, 38, 44, 49, 50, 52, 53] [PDF]; **E.2** UP IN THE AIR - How to Solve London's Air Quality Crisis: Part 2, 2016 [pages 2, 4, 11, 43, 50] [PDF]; **E.3** Policy Exchange website: 'A Ten Point Plan to Clean up London's Air' 2016

(F) UK Government's Clean Air Strategy: DEFRA, 2018 [page 51, item 68] [PDF]

(G) UKRI & Met Office appoint Clean Air Champions: Air Quality News, 2019

(H) Sources that corroborate Prof Kelly giving expert advice: H.1 The Health Impact of Air Pollution - An expert report of the International Society for Environmental Epidemiology and the European Respiratory Society 2019 [page 6, reference 20]; **H.2** Driving improved air quality through technology & collaboration: A white paper by Johnson Matthey and the Future Cities Catapult 2018 [pages 7, 8, 12,14]

(I) Sources that corroborate Prof Kelly giving evidence to the House of Commons Environmental Audit Committee in 2016: I.1 House of Commons Environmental Audit Committee - Environmental impact of microplastics - Microplastic Pollution: Sources of microplastic pollution [items 9, 22 and 32; references 57, 58, 61, 65]; **I.2** News article by the Independent: 'Scientist warns we could be breathing in microplastic particles laden with chemicals' 2016

(J) Defra Phase 2 urban model evaluation: King's College London, Cambridge Environmental Research Consultants, Imperial College London, Ricardo-AEA - October 2013

(K) Sources that corroborate King's researchers being members of important government groups: K.1 Committee on the Medical Effects of Air Pollutants: Membership; **K.2** COMEAP - The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom: A report by the Committee on the Medical Effects of Air Pollutants [page 98] **K.3** Air quality expert group: membership details – UK, DEFRA, 2018

(L) Sources that corroborate King's researchers collaborating with international researchers to provide expert advice to policy makers in Beijing, Paris and Hong Kong: L.1 (Beijing) Kelly FJ, Zhu T. Transport solutions for cleaner air. Science. 2016;352(6288):934-6. doi: 10.1126/science.aaf3420. PMID: 27199415; **L.2 (Paris)** Font A, Guiseppin L, Blangiardo M, Ghersi V, **Fuller GW**. A tale of two cities: is air pollution improving in Paris and London? *Environ Pollut*. 2019;249:1-12. doi: 10.1016/j.envpol.2019.01.040. PMID: 30875529; **L.3 (Hong Kong)** Mason TG, Chan KP, Schooling CM, Sun S, Yang A, Yang Y, **Barratt B**, Tian L. Air quality changes after Hong Kong shipping emission policy: An accountability study. Chemosphere. 2019;226:616-624. doi: 10.1016/j.chemosphere.2019.03.173.

(M) WHO Expert Consultation: Available evidence for the future update of the WHO Global Air Quality Guidelines (AQGs) Meeting report Bonn, Germany, 2015 [page 6, 38]

(N) Sources that corroborate King's researchers being members of influential national and international scientific panels: N.1 UN Economic Commission for Europe Executive Body for the Convention on Long-range Transboundary Air Pollution Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe Working Group on Effects (2018) [page 4] [PDF]; **N.2** Systematic Literature Review on the Health Effects of Long-term Exposure to Traffic-Related Air Pollution, Health Effects Institute Website, 2018