

Ricardo Quarterly Review

Summer 2021

# RQ

A focus on the latest in innovation,  
sustainability and technology



## **Clearing the air**

How new lockdown insights could bring global environmental improvements

## **Ready for take-off**

Delivering the world's first hydrogen-powered, passenger-carrying airline service

## **Ticket to ride**

A cleaner role for buses in the metropolitan transport mix

# The future of urban mobility

## How do we get there?





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Standards  
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EU's CO<sub>2</sub> Regulations  
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# RQ NEWS

Latest developments from around the global Ricardo organisation

## Research engine boosts Ricardo's hydrogen capability



Ricardo's hydrogen-fuelled research engine could provide the technology to decarbonise high-emission categories of vehicles

A hydrogen-fuelled research engine which could offer a renewable, economic and durable technology solution to accelerate zero carbon emissions in heavy duty trucks, off-highway machines and marine vessels has been created by Ricardo.

The engine could provide cost-effective, clean and trusted technology to decarbonise categories of vehicles which currently contribute a quarter of all on-highway transportation CO<sub>2</sub> emissions

across the European Union.

Ricardo will be testing the prototype at the state-of-the-art engine development facility at the University of Brighton – the company's long-term combustion engine research partner. The test programme will evaluate the performance, efficiency and emissions of the engine to assess its feasibility as a future multi-cylinder engine which could be taken into production for Ricardo's global customers.

"Green hydrogen has a critical role to play in our future energy and transport systems, particularly in reducing greenhouse gas emissions from hard to decarbonise sectors," says Adrian Greaney, Director of Technology and Digital at Ricardo Automotive and Industrial EMEA Division.

"We are working with a range of clients on hydrogen and renewable fuels to reduce carbon emissions in these challenging sectors. This exciting project with the University of Brighton sits alongside our developments in hydrogen fuel cell systems to deliver cost effective, clean and efficient solutions for our global clients."

The ongoing programme will use the real-world results from the hardware to validate methods applied in Ricardo's leading-edge digital tools. Virtual hardware optimisation and controls calibration will provide customer solutions that are more economic, efficient and sustainable.

The hydrogen-fuelled engine is a further boost to Ricardo's hydrogen capability, following the company's recent investment in a hydrogen development and test facility at its Shoreham Technical Centre.

As on-highway original equipment manufacturers face stringent European emissions regulations (a 30 per cent improvement against 2019 CO<sub>2</sub> fleet average by 2030, and an expectation that this target will be raised), Ricardo's hydrogen engine technology can help this transport sector progress towards achieving zero carbon emissions.

## Critical safety upgrades for US Army

Three-year contract to protect thousands of HMMWV operators

Ricardo Defense has won a base contract to provide up to 9,480 critical safety improvement Antilock Brake System/Electronic Stability Control (ABS/ESC) retrofit kits over the next three years for the US Army's High Mobility Multipurpose Wheeled Vehicle (HMMWV).

The contract, worth up to \$89 million, includes delivery of 1,200 ABS/ESC kits by August. A second delivery order is expected later this year.

The HMMWV is projected to remain in the US Army's fleet until 2050. Three years ago, the Army mandated that all new HMMWVs must have the ABS/ESC system installed. Since July 2018,

more than 5,000 new production or recapitalised HMMWV vehicles have been delivered to the US Army with Ricardo's ABS/ESC technology.

In 2019, the Army brought Ricardo's retrofit kit into the national stock system for vehicles not addressed during new production or recapitalisation. This dual approach ensures that all HMMWVs in the fleet will eventually be equipped with the rollover mitigation technology.

Data from the National Highway Traffic Safety Administration shows that the application of ABS and ESC reduces the number of fatal rollovers by 74 per cent and fatal impacts by 45 per cent.



## Double success at the British Engineering Excellence Awards

Ricardo Performance Products Division wins British Engineering Excellence Awards (BEEA) Consultancy of the Year and champion of champions 'Grand Prix'

The BEEA Consultancy of the Year 2020 award was for Ricardo's innovative industrialisation consultancy service, N2PI (Niche New Product Introduction). The service distils automotive engineering, manufacturing, commercial and strategic consultancy expertise garnered over the last 100 years to help growing businesses bridge the gap from concept to production; to ramp up as quickly, effectively and efficiently as possible without compromising cost or quality; and to minimise investment and provide a 'quick start' to the industrialisation process.

N2PI also supports companies in sectors not traditionally associated with Ricardo's automotive heritage but which operate in similarly demanding sectors – from healthcare to renewable energy – and require high performance with stringent safety and quality requirements.

To identify the Consultancy of the Year, the BEEA judges looked for companies that are developing innovative and timely solutions to their customers' engineering problems.

Other factors included the ratio of consultancy staff to the number of projects delivered, number of staff applied to those projects and their success. The judges were also interested to see how the consultancy has developed during the last five years and how it plans to grow its business.

In their citation, the judges stated: 'A great consultancy is one that not only thinks critically but takes a client on a journey, from concept to commercialisation. Ricardo has delivered just that. Across the board Ricardo has proved itself, time and again, as a trusted supporter of companies delivering innovative solutions effectively and efficiently.'

"Over the past year, we have all witnessed the urgent need for companies to bring

new products to market quickly, safely, successfully and cost-effectively," says Martin Starkey, Managing Director of Ricardo Performance Products.

"From ventilators to PPE to electrified transport, companies of all sizes around the globe have had to respond to real short-term or longer-term market needs and be able to industrialise their innovation with confidence.

"My team deploys these skills to develop and manufacture a new generation of products, aligned with the widely acknowledged industry megatrend of increased electrification, with high voltage batteries and mechanical systems for electrified vehicles forming a key part of the future strategy.

"These services are provided to external clients active in the development of technologies meeting the global need to reduce reliance on fossil fuels and cut harmful emissions. This area is seeing unprecedented focus and significant investment – an ability to 'bridge the gap' from concept to production will help accelerate the low carbon future."

Ricardo Performance Products was also shortlisted for two other BEEAs: Design Team of the Year and Mechanical Product of the Year, for the design and manufacture of the high-performance transmissions used in the all-electric Formula E series.

In other awards news, Ricardo received double recognition in the Financial Times's annual rating of the UK's leading management consultants. The Ricardo Energy & Environment team's work on high-profile net zero and decarbonisation projects was awarded a silver medal after three previous bronze medals. And the Ricardo Strategic Consulting team was recognised for the first time, winning bronze for its expertise in the automotive sector.

## Ricardo joins Getting to Zero Coalition

Aim of delivering the world's first commercially viable zero-emission seagoing vessel

The International Maritime Organisation has set an ambition of reducing greenhouse gas (GHG) emissions from shipping by at least 50 per cent by 2050. Ricardo experts are already playing an active role in supporting this, including developing world-leading maritime GHG emission inventories that support policy development; evaluating the opportunities and benefits of generating renewables-based electro-fuels; and devising next-generation clean vessel propulsion solutions.

Getting to Zero is a business-led global coalition that works with and through the shipping industry sector. Its aim is to develop and implement commercially viable zero-emission vessels operating along deep-sea trade routes by 2030, supported by the necessary infrastructure for scalable net zero carbon energy sources including production, distribution, storage and bunkering. The coalition is a partnership between the Global Maritime Forum, World Economic Forum and Friends of Ocean Action.

"Ricardo is actively supporting the decarbonisation of the global transport and energy sectors," says Dr Mike Bell, Ricardo Group Strategy Director. "We recognise the critical role the maritime industry plays in reducing the impacts of climate change. We are already developing clean, efficient products for the maritime sector, advising international governments and policy makers, and acting as a trusted advisor to the industry on solutions to achieve net zero.

"Joining the Getting to Zero Coalition will enable us to work proactively with our new partners, applying our proven solutions to reduce carbon emissions and deliver clean, efficient solutions so that the marine sector can achieve its ultimate goal of halving emissions from shipping by 2050."





## Feasibility study for niche UK-based battery manufacturing facility

Ricardo has received UK Government funding to assess the commercial viability of a facility to assemble battery packs for UK manufacturers which produce fewer than 10,000 electrified vehicles (EVs) per year.

The company will leverage its expertise in niche volume manufacturing, battery research and development, second life and recycling, complex supply chain management and strategic consultancy to 'level up' the UK supply chain in critical EV components.

These manufacturers include some of the world's best known prestige brands which create their luxury cars, special vehicles or off-highway machines for a customer base in the low thousands. This compares to the hundreds of thousands of vehicles produced for the mass market.

Funded by the Advanced Propulsion Centre's Automotive Transformation Fund supported by the Department for Business, Energy and Industrial Strategy, the economic study will consider how to meet the particular battery hardware needs of these diverse manufacturers across a wide range of business sectors,



by ensuring a UK supply chain in EV components.

"The UK automotive industry has a diverse mix of sector-leading manufacturers," says Martin Starkey, Managing Director for Ricardo Performance Products. "The volume requirements and flexible product specifications of niche volume manufacturers are not aligned with the high-volume outputs from emerging 'gigafactories'.

"A niche volume battery manufacturing facility will help to establish a robust supply chain for these critical electrification components. In doing so, it will deliver national competitive advantage for the UK and support the mass adoption of electrification by making it more affordable, helping to contribute to the green bounceback through sustainable practices."

As part of the study, Ricardo will assess how the proposed facility could help minimise the risk of scaling up the innovation of new battery concepts to niche volumes. The company will also explore opportunities to minimise the environmental impact of battery pack manufacture through 'second life processing' and recycling of core elements from construction.

**A niche volume battery manufacturing facility will help to establish a robust supply chain for critical electrification components**

## Ricardo North America set to Elevate

Launch of advanced technology for electrified, connected and automated vehicles

Ricardo North America has unveiled its reference Service-Oriented Architecture, known as Elevate: a standards-based starting point for developing next-generation embedded systems to ensure scalability and reuse across vehicle programmes, makes and models.

Elevate removes dependencies on the underlying operating environment and hardware, ensures interoperability between vendor solutions and reduces system and integration complexity across the stack.

"As an industry we have struggled to take R&D developments to production scale, seeing large amounts of engineering waste across different programmes, platform upgrades and hardware evolutions," says Madison White, Senior Manager, Marketing and Solutions Strategy.

"Our goal is to deliver a standards-based starting-point that provides the flexibility and interoperability needed to accelerate development and production-scale deployment of next-generation embedded systems. Elevate provides original equipment manufacturers and Tier 1s with the solution-agnostic architectural guidance they need to accelerate their development of differentiated solutions.

"We are seeing an accelerated rate of change driven by the convergence of electrification and software, which will enable a new world of cleaner and more efficient mobility solutions. Our Elevate architecture and system integration expertise deliver the baseline starting point for customers to take this vision to production-scale reality."

## Ricardo joins Scottish hydrogen association

The Scottish Hydrogen and Fuel Cell Association (SHFCA) helps to endorse and advance Scottish expertise in the hydrogen and fuel cell arena and give its members a voice in the industry's future. Ricardo has joined the SHFCA in order to raise its profile in the hydrogen sector.

"It was a natural step for us to join the SHFCA," says Colin McNaught, Ricardo's Head of Transport Energy Infrastructure. "Membership will provide us with links to potential partners in the sector for collaborative projects, and new links to companies in the energy sector in Scotland."

Ricardo is involved in hydrogen projects across all transportation sectors. The company manages the UK grant scheme for hydrogen refuelling stations for vehicles, as well as undertaking assessment of green hydrogen and green ammonia in around 10 countries for marine vessels.

Ricardo has also assessed the costs of hydrogen for the rail sector and provided certification for the first hydrogen train to run on the UK network while, in the air, specialists are leading the development of a hydrogen fuel cell solution to power a nine-seater aircraft [see 'Hy in the sky', p20-22].

A VIEW FROM

## Three ways the EU can change the global maritime emissions game

Jill Duggan, Executive Director, Environmental Defense Fund Europe



**Jill Duggan oversees EDF Europe, drawing on her extensive international career in climate, environment and energy policy. She is developing EDF's strategic vision for Europe, building partnerships with key EU stakeholders, and drawing on EDF's strong science and economics base to provide cross-cutting resilient solutions to 21st century environmental challenges.**

Emissions from international shipping comprise nearly three per cent of anthropogenic greenhouse gases (GHG) released worldwide. Those emissions are currently on track to increase. In the European Union (EU), shipping emissions represent around 13 per cent of the block's transport-related GHG emissions.

With the climate crisis in full swing, the EU has realised the need to act quickly to curb emissions in the context of sweeping reforms as part of its European Green Deal. We believe it can do more to set the low-carbon trends that the international shipping world desperately needs.

### Boosting alternative fuels

The shipping sector is on the cusp of a dramatic fuel and technological shift needed to meet global climate goals. Electrofuels, namely green ammonia and hydrogen<sup>1</sup>, can be produced at scale using

wind energy some 20 years ago, they should push the right mix of market-based incentives that can support innovation to make these technologies the obvious choice for shipping companies.

### Counting more carbon with the EU's Emissions Trading Scheme

The European Commission is set to release its 'Fit for 55' package this summer to update the EU's climate and energy laws to reflect an emissions reduction target of 55 per cent for 2030. Among the initiatives will be the inclusion of shipping in the EU's Emissions Trading Scheme (ETS).

Still unclear, though, is the scope of the inclusion: will it cover international emissions or just those inside the EU? And will it take a lifecycle approach to count carbon emitted not only at sea but also through other shipping-related activities on land?

Debate on this has been heated, with shipping companies in fierce opposition<sup>2</sup> to any inclusion at all in the ETS. For Environmental Defense Fund Europe the way forward is clear: the EU needs to count as much carbon as possible and use this pot of money to fund the transition to sustainable fuels.

### The EU as global climate diplomat

Europe has a long history of translating climate commitments into policy frameworks that deliver results. With shipping, the EU has a first-mover opportunity to tackle a sector which has so far evaded extensive regulation and set an example for other countries to follow.

The EU already considers itself a world leader on climate and would do well to throw its weight and expertise around more in the corridors of the International Maritime Organization.

Between the EU and US, "the stars have never been more aligned on climate", according to ranking environment Member of European Parliament Pascal Canfin at a recent event<sup>3</sup> supported by Environmental Defense Fund Europe.

The EU should seize on this new momentum to team with the Biden administration to fast track the kind of quick wins and systemic policy change needed to start and maintain the global shift towards low-carbon shipping essential to limiting global heating.

“WITH THE CLIMATE CRISIS IN FULL SWING, THE EU HAS REALISED THE NEED TO ACT QUICKLY TO CURB EMISSIONS IN THE CONTEXT OF SWEEPING REFORMS AS PART OF ITS EUROPEAN GREEN DEAL”

commercially available technologies and deployed at scale relatively quickly.

As with any fledgling technology, financial support is needed to move these low-carbon options into the mainstream. Just as the EU began to do for solar and

<sup>1</sup> [edf.europa.org/alternative-fuels-shipping](https://edf.europa.org/alternative-fuels-shipping)

<sup>2</sup> [bit.ly/3ht70ww](https://bit.ly/3ht70ww) <sup>3</sup> [bit.ly/3bkrXxZ](https://bit.ly/3bkrXxZ)

<sup>3</sup> [bit.ly/3bkrXxZ](https://bit.ly/3bkrXxZ)



## THE BIG PICTURE

The *New York Times* once began an article about the capital city of Bangladesh with the lines: 'I was in Dhaka, which is to say I was stuck in traffic. The proposition might more accurately be phrased the other way around: I was stuck in traffic therefore I was in Dhaka. Dhaka's traffic is traffic in extremis, a state of chaos so pervasive and permanent that it has become the city's organising principle.'

The city's transportation system was modelled on the concept of moving 88 per cent of passengers by buses occupying 50 per cent of the road space. The reality is that private vehicles – often old and heavily polluting models – occupy 70 per cent of road space with the buses using just five per cent.

The consequence, as well as endless gridlocks for business as well as private road users, is that Dhaka's air quality ranges from bad or unhealthy to very unhealthy for around 300 days each year.

In December 2020 the Bangladeshi Government set an ambitious target for at least 15 per cent of the country's registered vehicles to be powered by 'environment-friendly electricity' by 2030. With a view to making it possible, Ricardo has received funding from the UK Government's Department for Business, Energy and Industrial Strategy to help organisations in Bangladesh access finance to invest in new electric vehicles (EVs).

The project is backed by the UK PACT Green Recovery Challenge Fund and forms part of the UK's commitment to tackle climate change by aiding eligible partner countries in their move towards a low-carbon sustainable future.

"A lot of businesses in Bangladesh want to make the move to more sustainable transport," says Ricardo's Programme Manager, Arbaaz Nayeem. "The cost of financing, awareness of products and confidence in the business models have proved to be major barriers. We want to make it easier for them to take advantage of the different transport options available."

Experts from Ricardo and Bangladeshi partner organisations will first seek to understand the needs of small enterprises and evaluate the current finance options before developing a financing product.

The team will then work with organisation owners to develop business cases and make funding applications to banks. Small enterprises, many run by female entrepreneurs, will be helped to apply for financing for sustainable and electric transport.

"We have the knowledge to make a genuine difference in a country where EVs are not as financially accessible as they could be," says Arbaaz. "We will create an enabling environment for EVs in Bangladesh with a focus on affordable and accessible finance; and scalable, inclusive business models for the EV ecosystem, thereby delivering accelerated, business-led emissions reduction.

"We aim to support the country in its development vision by delivering sustainable, inclusive growth on the Road to Building a Green Bangladesh."



# SOMETHING IN THE



Last year's lockdowns offered a unique opportunity to examine the contributions made by different vehicle types to urban pollution. **David Carslaw**, Ricardo's Air Quality Knowledge Leader, explains how insights gained from novel road traffic and vehicle emission remote sensing data could help bring about future environmental and health improvements.



The COVID-19 lockdowns of the last 15 months inspired compelling photography from around the world. Few images were more powerful than those showing the impact of reduced air pollution due to restrictions on human and business activity.

In India, people living in the northern state of Punjab were able to see the snow-capped Himalayas, 200 kilometres away, for the first time in 30 years.

From Manila to Madrid, 'before and after' photos depicted cities in sharp relief rather

than enveloped in their usual yellow haze.

A number of internationally respected authorities, including the European Environment Agency (EEA) and North American Space Agency, have documented the dramatic improvement in key air quality pollutants such as NO<sub>2</sub> and Particulate Matter (PM) during the pandemic, most notably in some of the world's hotspots.

For cities across Europe, the EEA's air quality and COVID-19 tracker demonstrated that concentrations of NO<sub>2</sub>, a pollutant

commonly associated with road transport [see 'Take a deep breath', p13], fell significantly where lockdown measures were implemented in the spring of 2020. During the lockdown restrictions in April that year, concentrations of NO<sub>2</sub> were estimated to decline by 61 per cent in Spain, 51 per cent in France and 45 per cent in the UK.

Concentrations of PM<sub>10</sub> were also shown to have declined across Europe in this period; however, the observed decreases were less pronounced due to the complex

nature of sources of PM.

A report<sup>1</sup> in *The Lancet* noted that lockdown interventions led to substantial reductions in PM<sub>2.5</sub> concentrations in China and Europe with tens of thousands of premature deaths from air pollution avoided; and that considerable improvements in air quality are achievable in both China and Europe when stringent emission control policies are adopted.

However, there are already signs that pollution levels are returning to levels closer

to those observed prior to the pandemic. Concentrations of pollutants such as NO<sub>2</sub> in towns and cities are likely to continue to rise as restrictions are lifted and congestion increases. This situation may be exacerbated by concerns over the potential risks of infection associated with crowded public transport, in preference to 'safer' private vehicles.

Alternatively, pollution levels may stabilise or even decline if society embraces flexible working arrangements and more

sustainable forms of transport, notably cycling and walking. Governments, authorities and agencies are responding proactively to the anticipated 'new normal' and seeking to embed cleaner, safer transport behaviours for the long-term.

Overleaf, David Carslaw discusses how periods of lockdown over the last 15 months have provided a unique opportunity to understand in greater detail the contributions made by different vehicle types to urban NO<sub>x</sub> and NO<sub>2</sub> emissions and concentrations.





# MADE TO MEASURE

**Ricardo has the longest-established specialist air quality team in the world and, with over 130 experts, one of the largest.**

The company has worked with all levels of government, organisations and businesses for more than 60 years to understand, manage and deliver progressive improvements in air quality.

Ricardo supports the UK Government's Department for Environment, Food and Rural Affairs to deliver quality assurance and quality control services to the UK's largest air quality monitoring network, the Automatic Urban and Rural Network (AURN).

This important UK-wide air pollution monitoring work helps the UK Government fulfil its statutory European reporting requirements, as well as supporting air quality research and policy development. The data produced by the network underpins policy made at both local and national levels.

AURN has been delivering data since the early 1970s and comprises 149 monitoring stations across the UK producing 5.5 million measurements every year. As data volumes increase, Ricardo continues to lead the way in Europe in establishing common quality assurance procedures for efficient and open reporting.

## Measuring real-world driving emissions

In 2017, the company launched its remote sensing vehicle emission measurement service and database. This system accurately measures real-world driving emissions from thousands of vehicles, under actual driving conditions, quickly and without interference to the vehicle being measured. The database now holds around 600,000 measurements from across the UK.

Ricardo also has a team of more than 30 air quality modelling specialists whose work includes designing, managing and operating the UK's Air Quality Forecasting system for more than a decade.

Among its solutions is **RapidAir®**, a ground-breaking air quality dispersion modelling software that gives the ability to visualise air quality at high resolution and quickly test the impact of development or mitigation scenarios.

RapidAir® enables city-scale air quality levels, including complex domains such as mega-cities, to be calculated and updated in minutes. The software has been used extensively around the world, including in Beijing, Jinan and London.

*Find out more about Ricardo's air quality services at: [ee.ricardo.com/air-quality](https://ee.ricardo.com/air-quality)*

**Ricardo has sought to understand, manage and deliver progressive improvements in air quality for more than 60 years**



→ A major contributor to global decreases in air pollution during periods of lockdown was the greatly reduced level of road traffic. Data from 416 cities tracked by location technology company TomTom showed that, in 2020, 387 saw an average 21 per cent reduction in traffic compared to 2019. Of the 10 cities with most days of below-normal traffic congestion, nine were in the US, with Minneapolis and Nashville leading the way.

A frustration with the analysis of air quality data, however, is the lack of representative vehicle activity data. Traffic measurement devices may differentiate between, say, a short vehicle and a long vehicle but rarely more than that. This makes it harder to analyse air pollution data in terms of the influence of traffic.

Combining detailed traffic vehicle information with real world emissions data offers the potential to make more contextual sense of the pollution data we observe. It can provide greater insight into the site-specific sources of pollution and support the identification and implementation of effective mitigation measures.

If you can attribute certain levels of air pollution to particular vehicle types, then you have a much stronger grasp of the levers to pull in order to change things. With pollution

from road vehicles, you've got tens of millions of individual sources moving around in space and time. This is an inherently difficult problem: we're not looking at, for example, a single, static power station with a known level of emissions. Trying to capture this complexity is challenging.

During 2020, Vivacity Labs Limited supported the UK Department for Transport's national monitoring initiative to assess the impact of COVID-19. A novel camera-based sensor developed by Vivacity gathers greater detail about different road users compared to conventional sensors based on electro-magnetic interference or radar signals. The Vivacity sensor can differentiate between a car and a van (LGV), a bicycle and a motorbike, and a bus and a heavy goods vehicle (HGV).

A diverse range of Automatic Number Plate Recognition (ANPR) and mobility camera systems are currently used at locations across the UK road network for a wide range of purposes, including low-emission zone enforcement. Such systems offer the potential to provide detailed information on vehicle fleet composition which, when combined with Ricardo's real-world emission data, offers unprecedented insight into local air quality and how it can be managed most effectively.

The backdrop of a year's recurring lockdowns and reduced traffic levels gave a unique opportunity to assess the true impact of certain vehicle types on these ambient concentrations. This is explored in an article<sup>2</sup> I wrote with Peter Mildon, Chief Operating Officer at Vivacity.

## A question of attribution

Data from 440 sites, including 10 city centres, captured more than 800 million

traffic movements over a 13-month period. We were able to couple this detailed traffic information with around 600,000 real-world emission remote sensing measurements from our database at Ricardo, across all vehicle types, to obtain comprehensive information on the contribution to urban NOx emissions made by different vehicle types (see 'Made to measure'). In terms of remote sensing measurements, this is the largest data set available in the UK and probably one of the largest in the world.

Most of the information around the impact of COVID-19 on air quality has been to do with how air pollution measurements have detected changes in the concentration of different pollutants such as NO<sub>2</sub>. What previously was harder to interpret was any underlying change in emissions. What was driving these changes? This brings attribution into the discussion – how much of the change is due to changes in passenger car numbers, or the number of bus users, and so on?

We found that before any lockdown, passenger cars contributed almost 60 per cent of total NOx emissions and buses 17 per cent. During lockdown periods the contributions due to different vehicles changed. The passenger car portion fell to 53 per cent while LGVs and HGVs together contributed just under one-third of total NOx.

Most of the change we saw was in the passenger car fleet rather than vans and lorries, which obviously has consequences for the changes in emissions. A reduction of x per cent in vehicle numbers, for example, doesn't necessarily correspond to the same reduction in emissions because a car emits differently to a bus or another vehicle. This kind of attribution is providing important information on the full chain of changes in emission levels. And that's an important new

component of air quality management.

The topline figures hide a huge amount of detail. For example, the emissions represent in-use vehicle fleets measured in a wide range of UK urban areas and take into account fuel type, vehicle age, technology and mileage split. They represent emissions under real driving conditions and the effects of factors such as ambient temperature and any deterioration effects.

The data also provide a consistent measurement of emissions from a large range of vehicle types. Indeed, the emissions data is ideal for this purpose and in future ought to represent the most robust way of quantifying the contribution made by vehicles to NOx emissions.

In addition, reduced NOx emissions during the first UK lockdown and continued reduced emissions in late 2020 and into 2021 are evident. The vehicle measurement data strongly suggests that even in late February 2021 vehicle flows remained well below typical values, which translates to lower overall NOx emissions.

With the combined insight from vehicle emissions measurements and detailed traffic information, we estimate that, in the UK, road vehicles contribute to 77 per cent of urban NOx concentrations and about 66 per cent to NO<sub>2</sub> concentrations. There is a difference, however, between roadside and urban background locations, with roadside locations seeing a 78 per cent contribution of NOx concentrations from road vehicles and urban background sites seeing a 55 per cent contribution.

## Moving from data to policy

What these results show is the continuing significance of road vehicles in terms of their contribution to NOx and NO<sub>2</sub> concentrations



**David Carslaw is Ricardo's Air Quality Knowledge Leader. He has a PhD and MSc in Atmospheric Science and a BSc in Physics, together with more than 20 years' experience in air pollution science. He previously worked at the Environmental Research Group at King's College London and the Institute for Transport Studies at the University of Leeds. David leads the open source 'openair' project that has developed and made available many innovative data analysis techniques. He has been a member of AQEG (Air Quality Expert Group) since 2002.**

– and the need to further reduce emissions, even after decades of increasingly stringent emissions control. After all, road vehicles are still going to be dominant in most urban areas for some time to come.

From a policy perspective, source apportionment is important for the development of measures such as low-emission zones and clean air zones. Policy makers need to know the effect of a particular action: for example, if you were considering converting all buses to electric, you would need to understand the contribution buses made in the first place in order to understand the impact.

The data we now have presents a national picture for typical urban areas. The next step is to analyse at a local level in order to understand the spatial variation between different urban areas and the contribution to pollution made by traffic. London, for example, will behave quite differently to a city like Leeds, due to the different traffic mix and the contribution of other sources of air

pollution. It may be that in some locations the traffic component is lower or higher than is indicated in the analysis so far: establishing that quantitative apportionment is key to developing effective measures to control air pollution.

As for the global impact of the pandemic lockdowns on air pollution, it's clear that most of the beneficial changes have been due to greatly reduced levels of road traffic. It is, of course, a deeply unfortunate set of conditions that gave us the opportunity to live through the kind of change that previously could only have been simulated. However, we now have a chance to unpick some of the responses in terms of changing activities and emissions and see how they impact a whole range of air quality issues going beyond just urban pollution. This level of analysis will benefit every one of us. <sup>1,2</sup>

<sup>1</sup>Short-term and long-term health impacts of air pollution reductions from COVID-19 lockdowns in China and Europe: a modelling study: [thebmj.com/journals/bmj/article/PM2542-5196\(20\)30224-2/fulltext](https://thebmj.com/journals/bmj/article/PM2542-5196(20)30224-2/fulltext)  
<sup>2</sup>Urban air pollution insights through linking detailed road traffic and emissions data: <https://ee.ricardo.com/news/new-insights-into-urban-air-pollution-through-novel-road-traffic-and-vehicle-emission-remote-sensing>

**Source apportionment is important for the development of policy measures such as low-emission zones and clean air zones**

# TAKE A DEEP BREATH

## Air pollution – the causes and effects

### Fine Particulate Matter (PM<sub>10</sub> and PM<sub>2.5</sub>)

is tiny solid particles and liquid droplets suspended in air, comprising nitrates, sulphates, organic chemicals, metals, soil or dust particles and allergens. Particle pollution mainly comes from motor vehicles, wood burning heaters and industry. PM<sub>10</sub> particles (diameter of 10 micrometres or less) are small enough to pass through the throat and nose and enter the lungs. PM<sub>2.5</sub> particles (diameter of 2.5 micrometres or less) are so small they can get deep into the lungs and bloodstream. Long-term exposure can affect lung function and worsen medical conditions such as asthma and heart disease.

**Nitrogen dioxide (NO<sub>2</sub>)** is one of a group of gases called nitrogen oxides (NOx). It is formed by emissions primarily from motor vehicles and industry. High concentrations can be found near busy roads. Outdoors, NO<sub>2</sub> contributes to the formation of ground-level ozone (O<sub>3</sub>) as well as particulate matter pollution. It can cause breathing problems, headaches, chronically reduced lung function and eye irritation. Levels of NO<sub>2</sub> significantly reduced during lockdowns.

**Ozone (O<sub>3</sub>)** in the upper atmosphere protects us by filtering out damaging ultraviolet radiation from the sun but at ground level is the product of the interaction between sunlight and emissions from motor vehicles and industry. It is the main component of smog. The decrease in NO<sub>2</sub> during lockdowns brought a concomitant increase in average daily O<sub>3</sub> levels. The complex changes in emissions profiles during lockdowns is evidence of how a mass reduction in one pollutant can cause an increase in another, making it difficult simply to refer to air quality improvements.



# Transportation → Transformation

Carbon, capacity, cost and customer experience – these are four of the drivers for change within the urban mobility sector. How will technological advancements influence the way we move around towns and cities over the coming decades? And are some innovations merely solutions looking for a problem? Transport consultant **Leon Daniels OBE** discusses the challenges and opportunities for an autonomous, integrated and seamless future with RQ's **John Challen**.

The coronavirus pandemic has been responsible for many changes in our lives – none more so than our relationship with travel. Flying overseas for business may become a redundant concept while commuters and employers have recognised that many office jobs can be done just as efficiently from home. It remains to be seen whether these changes will become permanent; what is certain is that they pose fundamental questions about the future transportation needs of cities and their occupants.

"It would be lovely to develop a city's transportation system from scratch, without the limitations that exist," says Leon Daniels.

"I can't help thinking that there's some clever technology out there waiting to deliver a revolution but, in practice, revolutions are few and far between; most things merely evolve. Therefore, even if you were starting from scratch, I think you would struggle to develop anything that wasn't relatable to what is in place today."

He cites Cambridge as an example where, in 2016, residents were invited to suggest radical solutions to the city's chronic congestion and access issues. The majority of their ideas turned out to be related to vehicular or rail-based systems.

Daniels is, however, confident in predicting that urban transportation will become

more personal. "If starting with a clean sheet of paper, you would probably devise something like a high-tech equivalent of a driverless Uber," he reasons. "You wouldn't own it, you'd rent it. It would carry you from origin to destination, wouldn't have the huge associated labour costs, would be zero emission and would operate in an environment that excluded private motoring."

In reality, that concept would be difficult to implement in most existing UK urban areas due to the challenges of existing infrastructure. Elsewhere in the world, however, China is taking the lead in developing a number of new 'smart cities'



Leon Daniels believes successful transportation developments are more likely to come from discussion than drawing lines on maps and trying to create turnkey solutions

**"I can't help thinking that there's some clever technology out there waiting to deliver a revolution but, in practice, revolutions are few and far between; most things merely evolve"**

**Leon Daniels, transport consultant**



## LEON DANIELS – A CAREER ON THE MOVE →

Leon Daniels OBE was Managing Director Surface Transport at Transport for London (TfL) from 2011 to 2017. He kept the city moving during the 2012 Olympic and Paralympic Games and was responsible for delivering the UK's most ambitious cycle lane roll-out, the introduction of the capital's cycle hire scheme and serving as the Regulator for the taxi and private hire trade.

Before joining TfL, Leon was Managing Director at Capital Citybus and then Commercial Director at FirstGroup Bus, overseeing new ventures in UK and international transport. He now advises governments, agencies and companies including Ricardo.

Leon is a Fellow of the Chartered Institute of Transport, an Honorary Fellow of the Institute of Couriers and a Member of the Court of the Worshipful Company of Carmen.

Leon's popular 'Lunch with Leon' transport podcasts are available at: [www.leondaniels.co.uk/podcast](http://www.leondaniels.co.uk/podcast)



→ with transport innovation at their core.

Danish architecture firm BIG and Chinese tech company Terminus are planning a smart city development run entirely by AI in the south-western city of Chongqing.

Technology giant Tencent has unveiled plans for an almost entirely car-free 'city of the future' in the south-eastern metropolis of Shenzhen. Called 'Net City', the two million square metre development will prioritise pedestrians, green spaces and autonomous vehicles.

And in Xiong'an, 100 kilometres south-west of Beijing, what Spanish architects Guallart term a 'self-sufficient city' setting 'a new standard in the post-COVID era' is four years into construction with the aim of creating, say Guallart, 'a new urban life based in the circular bioeconomy that will empower cities and communities'. Again, active travel is at its heart.

"Big ideas in the UK also have the problem of elected mayors who have no money and typically aren't in post for long, which isn't conducive to good transport planning," Daniels adds.

To illustrate that point, and again in Cambridge, plans for a £2 billion autonomous metro may be scrapped following a change of leadership in May's local elections. Described by the previous incumbent as 'one of the most pioneering transport infrastructure projects seen in the UK', with a fleet of driverless pods ferrying passengers between 84 stops in the city and surrounding areas, the new mayor has called a halt claiming the project has 'all the hallmarks of being an expensive folly and a potential black hole for national and local government finances'.

### Testing two-wheeled solutions

A currently popular mobility solution is the e-scooter, even though it falls into a grey area from a legal standpoint. "In the UK, the 1930 Road Traffic Act included classification of motor vehicles, from which we have inherited specific categories: bike, motorbike, car, lorry, bus," explains Daniels. "What we're now seeing is innovation in transport solutions trying to find which 1930s category they fit into.

"E-scooters are an answer to many urban mobility issues but they don't have a legal category," he maintains. "I was pleased when the government announced last year that it would legalise rental trials of e-scooters run by local authorities. The 12-month test scheme set up by Transport for London and London Councils will play a vital role in helping to shape the UK's future policy on e-scooters, including whether they could form part of the capital's sustainable recovery from the coronavirus pandemic.

"In future I think we'll see every possible combination of bike, electric bike, scooter, electric scooter and electric moped in cities. But that creates other problems because as soon as you get on a moped, you're caught by the motorcycle Compulsory Basic Training (CBT) and crash regulations. Potentially, you could be on an e-scooter that's capable of

speeds of up to 40 kilometres per hour and not be required to take a CBT test or wear a crash helmet."

### Blurring the boundaries

The concept of the 'liveable neighbourhood unit' has been around since the 1920s but regained prominence during the pandemic as COVID-19 kickstarted a trend toward localisation. The idea of the '15-minute city' returned to the agenda of many metropolitan areas around the world, none more so than Paris where Mayor Anne Hidalgo placed it at the heart of her successful 2020 re-election campaign. Hidalgo has since appointed a commissioner for the 15-minute city to create what has been termed 'a city of proximities' – not only between structures but between people.

Autonomous vehicles (AVs) also offer the potential for a complete rethink around proximity and connectivity. "A real possibility with AVs is that our current demarcation of vehicles operating outside buildings and pedestrians operating inside them could become blurred," reasons Daniels. "Disney World is one of the only places where this blurring currently exists, because at the moment it is not practical for a small autonomous vehicle to be as useful inside a department store, for example, as it is

outside on the street."

Walt Disney's original vision for the Epcot theme park was to show the world what a perfect city could look like. Epcot was intended to serve as a model for how cities could be planned for maximum efficiency, including transportation by then-visionary systems such as monorails and PeopleMovers. "Autonomous vehicles have the potential to support a drive for efficiency by blurring the boundary between outside and inside – certainly in retail or industrial areas or on university campuses."

Regardless of what future autonomous solutions may emerge, there will – as in the case of e-scooters – be legal issues. Specifically, where responsibility lies when something goes wrong. Daniels believes more work needs to be done to address such matters and worries that slow progress is hampering innovation.

"The legislation isn't very helpful, because it's old," he explains. "Also, the UK Government's ability to find time for the topic is very limited. We need a widespread review of regulation relating to autonomous solutions but the Government is taking only small steps. It concerns me that I still read stories from the US about a single accident when someone's Tesla was in 'autopilot' mode but the fact that 102 other people were injured that day while driving a conventional vehicle doesn't even make the news."

### Mass transit, minimal footprint

Mass transit solutions are essential for cities to function. Recent developments have shown ways forward from traditional trains and trams. "I'm heartened to see how less obtrusive some of the major infrastructure for light rail has become," Daniels says. "BYD's SkyRail, for example, does not look like a monorail at all. We think of monorail infrastructure as big, heavy concrete, blocking out the sun, whereas the Skyrail structure is relatively light."

SkyRail can move up to 30,000 people per hour per direction using eight-car trains operating at two-minute intervals. Deploying an integrated, zero-emission, highly energy efficient power supply and distribution system, the energy created through on-board regenerative braking is stored in wayside batteries and high-power capacitors to pass on to other vehicles, stations and the electric power grid. A 23-kilometre SkyRail is underway in the Brazilian city of Salvador, while BYD is part of the LA SkyRail Express team proposing a system to link the San Fernando Valley to Los Angeles' Westside and its international airport.

While it is too simplistic to suggest that one country's solution will work elsewhere, lessons can be learned. "Kuala Lumpur is just

## “In future I think we’ll see every possible combination of bike, electric bike, scooter, electric scooter and electric moped in cities” Leon Daniels, transport consultant

exceptional," states Daniels. "It's got everything" – including a 14 km monorail, fully automatic trains, integrated ticketing for all rail-based systems and electric car sharing, built around the target of a 40 per cent public transport mode share by 2030.

A 2017 case study<sup>1</sup> by World Bank and Imperial College London cited capacity, connectivity and competition as key factors in the growth of passenger demand within Kuala Lumpur, achievable by investing in wide trains to maximise proven returns to density, connecting isolated transport projects into a system, and competing credibly against the highway network. By incorporating these elements into the organisation's culture and project development, Prasarana are increasingly moving towards being an urban development catalyst, rather than just a rail operator.

"I see other schemes in Asian cities that are addressing environmental and social issues," Daniels adds. "The Dubai and Riyadh metros are inspiring social change. In Riyadh, for example, the metro will enable more women to travel on their own in public. Transportation can become a cultural liberator, which is a huge benefit to society."

### Designing to meet a need

Daniels foresees a rightly greater emphasis on innovation that responds to the identified

needs of its users. "Too many companies have tended to say, 'We've got this great new idea. All you have to do is buy it from us and put it in your city'. They are trying to create an out-of-the-box solution that they hope users might like, but that often lacks alignment with future requirements. Successful products are more likely to come from discussion than people drawing lines on maps and trying to create turnkey solutions."

When it comes to something like Elon Musk's Hyperloop, deploying maglev vactrains for very-high-speed rail transportation, Daniels is likewise reserving judgment. "I've lived through so many of these ideas and a lot of them are solutions looking for a problem," he admits.

"Yes, it would be exciting to go from London to Edinburgh in 10 minutes. But maybe only once. The pandemic has taught us that people are now less willing to travel simply for the sake of travelling. There has to be a purpose to travel – and many of those purposes will have materially changed as we configure our post-COVID lives.

"Fifty years ago, experts predicted that by now we'd all be zooming around in flying cars. There's an argument to say that these hypersonic-speed concepts are just the modern-day equivalent." →

<sup>1</sup> [https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/centre-for-transport-studies/rts/world-bank/OperatorsStory\\_Kuala-Lumpur-Prasarana\\_Final-210717.pdf](https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/centre-for-transport-studies/rts/world-bank/OperatorsStory_Kuala-Lumpur-Prasarana_Final-210717.pdf)

SkyRail's infrastructure sits lightly within the urban landscape





# MOVING FORWARD →

Ricardo is in the business of making real things work properly. As these case studies show, the company has played a key role in developing connected and autonomous transportation technologies around the world – and will be helping to create the transit systems of the future



HydroFLEX, image courtesy of Porterbrook

One of the most successful projects has been the ULTra PRT (Personal Rapid Transit) system installed at Heathrow Airport's Terminal 5. Ricardo worked with the Railway Technology Strategy Centre at Imperial College London on an independent assessment of the project's deliverables and played a supporting role in its research and development. Twenty-one autonomous pods operate on a 3.9 km route between the terminal and business class car park. The pods

provide efficient personal transport that is also a greener alternative to traditional shuttle buses servicing other terminals and car parks.

Another environmentally friendly concept, for client Porterbrook, is the HybridFLEX rail programme which has helped reduce diesel emissions and converted trains to run in 'silent' mode. Ricardo provided expertise on the integration of a hybrid power pack into a converted diesel unit, the first time such a system was deployed on the UK rail network. An extension of the HydroFLEX project saw Ricardo support the creation of a hydrogen train prototype, converted from a Class 319 vehicle.

Further afield, Line S1 of the Beijing Subway is a maglev line operating on a 10 km route through two western districts of the city. Ricardo was appointed to ensure the safety of the line, which opened in 2017, and undertook a number of assessments and on-site audits. Safety on the maglev trains was of paramount importance, especially regarding the automatic operation and interlocking subsystem.

## CHINA CONNECTED →

One of the fastest-growing areas for metro railway networks is Asia. China is leading the way with its rollout of Communications Based Train Control (CBTC) signalling systems. The country is currently part-way through a project to extend its high-speed railway network to 30,500 km, connecting 27 major provinces with 11 state-of-the-art rail lines.

The CBTC system has been installed on more than 100 metro lines in some 40 cities around the world so far, making it the preferred choice of signalling system for railway operators. In China, Ricardo has been involved in a number of projects, such as the Qingdao metro, which featured the first CBTC system using local technology. Speeds of up to 160 kilometres per hour were possible and subsequent developments on the line have led to the adoption of Unattended Train Operation.

Elsewhere in China, Ricardo Certification, an independent and accredited approvals business within the Ricardo group,



has supported the installation of advanced transportation technologies on numerous networks. Working with global signalling supplier ASTS, the company has been responsible for independent safety assessments and certificate delivery at sites including Hangzhou, Chengdu, Zi'an and Tianjin.

**China is part-way through a major high-speed railway network extension**

## ULTRA-PUNCTUAL METRO IN THE DESERT →

Building a metro anywhere in the world is challenging enough; in Dubai, engineers faced one of the most hostile environments in which such a system has been built, with ambient temperatures ranging from 1°C to 52°C, winds blowing sand at up to 160 km/h and a corrosive atmosphere containing high levels of salt.

At the time of completion in 2011, this was the first urban train system in the Arabian Peninsula and, at 75 km in length, the world's longest driverless railway. Trains reach speeds of up to 85 km/h.

Ricardo Rail was appointed Independent Safety Assessor for the complete project, which proved to be one of the most demanding in the company's history. The metro serves 47

stations, 10 of which are underground with two functioning as line interchanges.

Nevertheless, six months after the metro started operations, its punctuality rate of 99.69 per cent was believed to be the highest of any driverless metro around the world.

**Dubai proved to be a demanding environment in which to build a metro system**



## KEEPING LONDON MOVING →

Ricardo played a key role in the development of the safety programme for the Thameslink project – a £6 billion initiative that has revolutionised train travel between the south of England and Kings Lynn on the Norfolk coast.

The project, completed in 2018, introduced longer trains onto the network, resolved bottlenecks on the line and improved stations such as London Bridge and Blackfriars. Central to the project was the 'Core' – a short, double-track section between Blackfriars and St Pancras which handled London's cross-city train traffic. This part of the line required a new signalling design

to help deal with 24 trains an hour (up from 16) and the ability to operate more like a metro.

Instead of using the CBTC system for its signalling – as typically seen in metros – Thameslink opted for the European Train Control System. This was overlaid on a conventional signalling system.

Remarkably, the whole project was managed while keeping the railway operational – an extraordinary achievement which Network Rail described as like 'performing open heart surgery while the patient is still awake'.



**Resolving bottlenecks and improving efficiency were among the aims of the Thameslink project**



# HY IN THE SKY

The jet engine revolutionised air transport, enabled today's global society and has been the principal propulsion system for aviation – until now. As the aviation sector looks to build back better after the global pandemic, sustainability will be at its heart. **Paul Hutton** and **Jenny Kavanagh** of Cranfield Aerospace Solutions tell **Kathryn Bellamy** about their ambitious plan to deliver the world's first truly green passenger-carrying airline service powered by hydrogen technology.



Looking forward to getting on a plane again and jetting off on holiday? You're not alone.

Despite the grounding of most of the world's aircraft during the global pandemic, air traffic has increased 20 per cent over the past five years and is still predicted to reach 10 billion passengers a year by 2050. This has largely negated the reductions in carbon dioxide emissions per passenger flight which have been made by the commercial aviation sector, thanks to improved engine technology and operational efficiency.

If the global commercial aviation sector is to bounce back greener from the worst crisis in its history, it needs technology solutions which can deliver zero carbon emissions but which, crucially, are also commercially viable.

Demonstrating that sustainable propulsion technology has a clear route to market is at the heart of Project Fresson. Named after Captain Ernest Edmund 'Ted' Fresson OBE, a British engineer and aviation pioneer who died in 1963, this research and development technology programme led by Cranfield Aerospace

Solutions is seeking to exploit recent advances in hydrogen fuel cell technology to develop a commercially viable, retrofit powertrain solution for the nine-passenger Britten-Norman Islander aircraft.

Hydrogen is not a new technology for transport. It was developed as rocket fuel for the US space programme in the 1950s and is currently used in heavy duty commercial vehicles, such as long-haul trucks and buses, because it offers not only zero carbon emissions but also cost-effective solutions in terms of total cost of ownership. Yet, despite this pedigree,

**Project Fresson is both an aircraft challenge and an operators' challenge: finding the right technology to deliver the mission that a service provider requires**

hydrogen has not been considered for commercial aviation until now.

## Achieving usable range

Paul Hutton, CEO of Cranfield Aerospace Solutions, explains what has changed: "Cranfield Aerospace and Britten-Norman look upon Project Fresson as an aircraft challenge and an operators' challenge. It's about finding the right technology successfully to deliver the mission that a service provider requires.

"We briefly considered pure battery electric to see if that had any chance

"IF THE GLOBAL COMMERCIAL AVIATION SECTOR IS TO BOUNCE BACK GREENER FROM THE WORST CRISIS IN ITS HISTORY, IT NEEDS TECHNOLOGY SOLUTIONS THAT CAN DELIVER ZERO CARBON EMISSIONS BUT WHICH, CRUCIALLY, ARE ALSO COMMERCIALY VIABLE"

of delivering what we wanted but, even before the formal project started, we realised we needed something other than just a battery to get a usable range.

"Having looked at the hybrid electric-range extender option, in some respects it looked quite promising. However, when we started doing detailed analysis and understanding the weight implications, whichever angle we took couldn't realise a solution which was greener than the original aircraft, while still being safe and that had operational credibility.

"In parallel," Hutton adds, "we were

looking at hydrogen as we had discovered very lightweight storage solutions to get the weight down because the tanks required to carry gaseous hydrogen can be very heavy. The availability of fuel cells with the right level of output was improving and the whole infrastructure around the availability of hydrogen as a fuel seemed to be accelerating at the same time.

"Having completed a comprehensive evaluation of technologies and configurations for sustainable aircraft propulsion, we concluded that hydrogen fuel cell technology is the optimum





## “PROJECT FRESSON WILL DELIVER AN EMISSIONS-FREE (ZERO CO<sub>2</sub>), HYDROGEN-FUEL-CELL-POWERED FLYING DEMONSTRATOR BY SEPTEMBER 2022”

→ solution to meet environmental, regulatory and operational requirements for this size of aircraft, enabling zero carbon emissions and reducing operating costs.”

In support of this, following a rigorous assessment of hydrogen technology innovators, Cranfield Aerospace Solutions brought Ricardo and Innovatus Technologies Limited into the consortium delivering Project Fresson.

Jenny Kavanagh, Chief Strategy Officer for Cranfield Aerospace Solutions, describes what both companies are bringing to the project: “Ricardo is providing the fuel cell system including its controller, which is the primary source of electricity on the aircraft. We selected Ricardo because of its industry-leading experience in systems engineering and model-based development approaches, as well as its expertise in fuel cell and thermodynamic or thermal systems development.

### Delivering efficiency improvements

“Ricardo has developed a process to improve the balance of plant components for multiple stack layouts for aerospace but also large applications requiring multiple stacks such as commercial vehicles, rail and marine. Its hydrogen fuel cell system development approach with multiple stacks balance of plant leads to an efficiency improvement of between five and 15 per cent depending

on duty cycle against the conventional approach of balance of plant and control development, so there are tangible performance benefits.

“Innovatus Technologies leads the field in next generation, ultra-lightweight hydrogen tank design exploiting patented cellular core composite techniques,” Kavanagh explains. “Project Fresson will use its innovative Scottish Hydrogen Fuel Tank (SHyFT) technology.

“Very novel latest generation carbon composite manufacturing techniques create multi-chamber hydrogen storage tanks which are super lightweight, very high pressure capable and completely formable to the application required. Aerodynamics are key, weight is paramount and hydrogen storage volume is a principal descriptor of the range of the system.

“Innovatus brings this technology into the programme to carry enough hydrogen efficiently in the form factor to release the performance of the platform. This is critical to the successful integration and exploitation of hydrogen fuel cell power systems in applications across aerospace, automotive, industrial, and marine sectors.”


### Proving commercial viability

The commercial viability of the technology is a key objective of the project. Hydrogen produces significant cost savings compared to avgas or avtur fuel alternatives. “The biggest saving comes from the expected market price

of hydrogen and the amount needed for a given flight,” says Hutton.

“The carriage requirements of hydrogen make it less storage dense, but the energy density is high so the amount of hydrogen you need is relatively small. Therefore operators can make a significant saving, especially for an aircraft such as the Britten-Norman Islander which has nine passenger seats. We estimate an annual operational cost saving of £150,000–£300,000 against current piston engine options, depending on usage and cost of hydrogen.

“There is also a maintenance cost saving as the elements of these technologies have fewer moving parts: we estimate that maintenance costs should fall by around 15 per cent for the whole aircraft and up to 50 per cent just for the propulsion system.”

Project Fresson will deliver an emissions-free (zero CO<sub>2</sub>), hydrogen fuel cell-powered flying demonstrator by September 2022. Subject to successful certification by the civil aviation authorities, the first flight with paying customers, which could take place by operators in the UK, will be the world’s first truly green passenger-carrying airline service using hydrogen fuel cell technology. 

For the latest news and updates on Project Fresson visit: [www.projectfresson.uk](http://www.projectfresson.uk) or follow on Twitter @projectfresson

Hydrogen fuel cells are considered an optimum solution for aviation



## THIS MUCH I KNOW...

### FIONA TWISSE

Senior Technical Consultant  
For Sustainable Transport,  
Ricardo Energy & Environment,  
on Sustainable Aviation Fuel and  
the ‘Green Fuels, Green Skies’  
competition



**Sustainable Aviation Fuel (SAF) is a drop-in liquid fuel that can be used in traditional aircraft.** Put simply, it’s produced from sustainable resources such as biogenic wastes, renewable electricity and waste-based fossil fuels. It’s not new – the first commercial SAF flight was in 2011 – but the UK’s challenging goals for reducing greenhouse gas emissions from transport have prioritised its production at scale.

**The aviation sector currently has few alternatives to using liquid fossil fuels.** Widespread use of SAF could reduce greenhouse gases from aviation by 70 per cent – and that’s a conservative estimate.

**Green Fuels, Green Skies (GFGS) is a competition launched in 2021 to support the UK’s emerging SAF sector on its journey to large-scale production.** Part of the UK Government’s Ten Point Plan for a Green Industrial Revolution, GFGS will provide up to £15 million in funding for the early-stage development of UK SAF plants – in other words, the Front End Engineering Design (FEED), pre-FEED and feasibility study stages of a project’s development life cycle.

**I’m project manager for GFGS, jointly delivered by Ricardo and E4tech.** Ricardo has worked with the Department for Transport (DfT) to support and manage projects for several high-profile national competitions. I manage other national programmes such as ‘Future Fuels for Flight and Freight’ to promote the development of an advanced low carbon fuels industry and the Hydrogen for Transport Programme for the Office for Zero Emission Vehicles which funds hydrogen refuelling stations and hydrogen fuel cell electric vehicles.

**Competitions like GFGS attract wide-ranging interest.** From entrepreneurs to academic institutions that are very often involved in the research and development phases. It really does scale from SMEs to global organisations and it’s inspiring to interact with such a range of enterprises.

**The deadline for GFGS submissions was the end of May, with each application scrutinised by technical and commercial experts to ensure all criteria have**

## “EARLY AND DECISIVE ACTION COULD SEE THE UK, WITH OUR RESEARCH AND ENGINEERING EXPERTISE, CLAIMING A SHARE OF A GLOBAL SAF MARKET”


### been met and the project will offer value for money.

This rigorous process ensures the best applications are selected for funding. We expect to announce the competition winners in late July with the funding period for project work running until the end of March 2022.

### By 2030, a domestic SAF industry could be worth over £400 million a year to the UK economy.

Up to 9,800 highly skilled jobs could be created, potentially in regions aligned with the Government’s levelling up agenda. Replacing imported kerosene with domestically produced SAF would also increase fuel security. And an independent feasibility study commissioned by the DfT from Ricardo and E4tech showed that early and decisive action could see the UK, with our research and engineering expertise, claiming a share of a global SAF market that itself could support UK low carbon growth.

### My wider project portfolio is enjoyably diverse.

It includes urban mobility, policy studies, developing and delivering grant programmes, assessing and reporting Member States’ transposition of EU Directives and communicating information to the industry. The role allows me to explore initiatives at every scale, from street level to national projects. I communicate with people from a wide range of backgrounds and sometimes hear two different perspectives and think: ‘Oh, we need to get you into a room together’. Being able to facilitate those discussions and communicate differing points of view is very rewarding given the significance of the issues at stake. 





# Just the TICKET

Buses play a key role in the urban transport mix – and are also a major contributor to air pollution within cities. How can we have one without the other?

In the year to June 2020, more than two billion passenger journeys were made by bus in London – representing 14 per cent of all travel.

Sound a lot? In Rio de Janeiro over a similar period, the city's bus rapid transit system recorded just over one *trillion* passengers, equating to 37 per cent of all journeys – one of the largest modal shares in the world.

A bus typically emits fewer greenhouse gases per passenger kilometre than a single occupancy car – 82g of CO<sub>2</sub>e per km compared to 180g for an average petrol car. However, since journeys are typically far longer than cars, the exposure to air pollution is higher. The number of buses on the road in many cities remains a significant contributor to air pollution: more than 16,000 operate daily in Kolkata, for example, helping to explain why it is the second most polluted city in India. Furthermore, according to the International Association of Public

Transport's 2019 Global Bus Survey, covering 320 operators in 46 countries, diesel still accounts for 50 per cent of propulsion systems used across the world.

A move from fossil fuel vehicles to zero-emission vehicles (ZEVs) will help address these issues. This is at the heart of the Clean Bus Declaration and Fossil Fuel Free Streets Declaration made by the C40 network [see 'Cities setting the global agenda'].

In the UK, the Government's Ten Point Plan for a Green Industrial Revolution, announced in November 2020, includes a National Bus Strategy. "Electrification is key," says Dr Mike Bell, Ricardo's Group Strategy and Transformation Director. "The strategy mentions funding for two all-electric bus towns and development of the first fully zero-emission city centre. A reference to £120 million for at least 4,000 'British-built zero-emission buses' perhaps leaves the door open for hydrogen-fuelled buses too."

## Navigating the route to zero

Ricardo is already working with customers across all global transport sectors to reach a sustainable zero carbon future, building on its expertise in the development of clean, efficient, integrated propulsion and energy systems for advanced battery electric and hybrid vehicles. The company's recent initial £2.5 million investment in a hydrogen test facility at its Shoreham Technical Centre is a clear statement of its vision to be a leader in hydrogen, defossilised fuels and electrified transport engineering.

The benefits of electrifying city buses are clear. They have predictable energy requirements based on repeat schedules which facilitate battery charging at depots. The Confederation of Passenger Transport, which represents 95 per cent of English bus operators, stated in 2019 that it plans to buy only zero-emission vehicles for use in cities. However, the route to an entirely zero emissions bus future is more complex, given the typical 10 to 15-year lifespan

of a vehicle and the existence already of regulated low and zero emissions zones through which to navigate.

Battery electric and hydrogen fuel cell solutions both have a part to play in the decarbonisation of buses. The optimum solution for a given operator will depend on factors such as the operational requirements and local energy infrastructure. Hydrogen could provide an increased range and greater flexibility on operating routes and schedules, compared to a battery electric bus that requires more frequent or longer charging periods.

"The major bus original equipment manufacturers (OEMs) are offering both battery electric and hydrogen fuel cell products, so the technical solutions for decarbonisation are known," says Will Missions, Chief Engineer at Ricardo. "The challenge is implementation. Buses have long service lives and so transitioning fleets to zero-emission vehicles will take many years, potentially decades, to complete.

"A key opportunity to accelerate decarbonisation is to make use of the existing assets and to retrofit the current

vehicles with zero-emission powertrains. Another potential solution being explored by many truck OEMs is hydrogen-fuelled combustion engines. This approach has advantages for fast adoption through minimising change to the vehicle powertrain and manufacturing infrastructure."

## Optimising for flexibility

Geofencing – creating a virtual perimeter for a real-world geographic area – is at the heart of a Ricardo project underway in West Sussex.

As reported in the Spring 2021 edition of RQ, Ricardo has received funding from the Geospatial Commission in partnership with Innovate UK to enhance the use of transport location data so that hybrid electric vehicles can intelligently modify how they operate.

"The project is about using geofencing to encourage more intelligent use of plug-in hybrid EVs, which have limited zero-emission range, to make sure they have the lowest possible impact on air quality" explains Josh Dalby, Ricardo's Chief Engineer for Technology Strategy.

"This application of geofencing involves adding smart on-board technology to

a hybrid EV, allowing it to 'sense' when it is in an ultra low emissions zone and automatically switch its operating mode."

Brighton & Hove Buses operates the UK's first zero-emission geofenced fleet of 54 buses which are fitted with this technology to enable them to sense when they are in pre-defined areas and automatically switch to zero-emission mode. "Our focus," Dalby adds, "is on optimising this fleet to enable it to use more flexible zones, rather than the current, static, pre-defined ones.

"During the first phase of the project, we are evaluating the benefits and feasibility of flexible geofencing both to existing buses and private vehicles. In the second phase, we plan to demonstrate this approach through some small fleet trials, while also developing the back-end system which would automatically define the optimum geofenced area for the different vehicles being driven in a city."

Beyond that? "We're looking to roll out and extend this technology to any city in the UK and, longer term, to any city internationally to reduce the emissions of existing fleets while fully zero-emission solutions mature and enter the marketplace." 

**City buses have predictable energy requirements based on repeat schedules which facilitate battery charging at depots**



**“Geofencing [can] encourage more intelligent use of plug-in hybrid EVs to make sure they have the lowest possible impact on air quality”**

**Josh Dalby, Chief Engineer for Technology Strategy, Ricardo**

## Cities setting the global agenda

**C40 is an alliance of 97 world megacities committed to addressing climate change. Representing more than 700 million citizens and one-quarter of the global economy, C40 convenes networks covering high-priority mitigation, adaptation and sustainability topics. Among them, the zero-emission vehicles (ZEV) network focuses on actions to facilitate the uptake of ZEVs.**

**In 2016, the C40 cities made a Clean Bus Declaration by incorporating low- and zero-emission buses in their fleets. The declaration was a call to manufacturers, operators, leasing companies and funding agencies to support city ambitions to decarbonise urban mass transport.**

**The following year, 12 cities led by London, Paris, Los Angeles and Copenhagen announced their vision for Green and Healthy Streets by signing the Fossil Fuel Free Streets Declaration. Collectively, the cities have committed to procure only zero-emission buses from 2025, and to ensure a major area of their city is zero-emission by 2030. A total of 26 cities have now signed this declaration, with a procurement potential of over 80,000 buses.**

[c40.org](http://c40.org)





# A day in the life...

## MARQUES McCAMMON

### President, Ricardo North America

We recently held our inaugural Ricardo Mobility Summit. I've grabbed a few moments to reflect on the title of our event and our broad theme: convergence.

We were online for seven hours in total, covering five panel discussions, a series of Ricardo technology previews and one-to-one 'Leader's View' interviews with executives from Ford, Microsoft and Toyota. We brought together propulsion experts, transport tech gurus, data activation experts, transportation authorities and private equity execs to explore how the environment, electrification, autonomy, digitisation and software are converging to define the future of mobility – not to mention the impact of more than a year of uncertainty caused by COVID-19.

What we're experiencing is half a century of change stuffed into the 2020s – a rare collection of issues and influences converging to overhaul the transportation landscape in our tech-first world. For Ricardo, an event like this is a chance to show how we develop transportation solutions to fit our customer's business, not the other way around.

Leaders within the mobility industry have a huge amount to focus on as we move into a period of post-pandemic recovery but it's clear that

propagating a sense of safety and well-being is vital. That's both internally to the organisations that are driving mobility solutions and externally to the constituencies that we support with our solutions.

The pandemic has threatened our everyday sense of well-being and exacerbated the need for people to find safety and comfort. This means the connection of technology and mobility that we are all interested in professionally also has to function emotionally as a bridge to the human experience.

We are already moving towards a world of connected, electrified and autonomous mobility. Our summit explored other key trends. First, how electrification is an enabler of other functions as it delivers greater power for services and processing power for applications such as connectivity, data processing and autonomous driving. The key being that electrified electronic control and propulsions system architectures will accelerate the roadmaps for other advanced functions – another point for convergence.

No less significant, and particularly relevant for Ricardo, is a blurring of the demarcation between transport modes. People will stop considering themselves


#### MARQUES IN BRIEF

**Title:** President, Ricardo North America  
**Education:** BS in Mechanical Engineering, North Carolina A&T State University; Master's in Mechanical Engineering, University of Michigan  
**Honours:** Identified by Crain's Detroit Business as one of 40 young executives making an impact in the Motor City  
**Joined Ricardo:** October 2019, after five years as head of automotive products and services with former Intel subsidiary, Wind River Systems, Inc.

**Dateline:** May 2021

**“WE’RE EXPERIENCING HALF A CENTURY OF CHANGE STUFFED INTO THE 2020S – A RARE COLLECTION OF ISSUES AND INFLUENCES CONVERGING TO OVERHAUL THE TRANSPORTATION LANDSCAPE”**

a rail user, car user, motorcycle user or aeroplane user and become simply a user of transport, moving seamlessly through modes. For this to happen, these segments will need to share knowledge, experiences and data and do so securely and robustly.

For me, this is an exciting and stimulating vision of our future. For all of us, it means the pace of innovation and development will inevitably quicken. 

View the Ricardo Mobility Summit keynote, sessions and Ricardo technology previews at: [ricardo-northamerica.com/events/ricardo-mobility-summit-2021](https://ricardo-northamerica.com/events/ricardo-mobility-summit-2021)

# RQ

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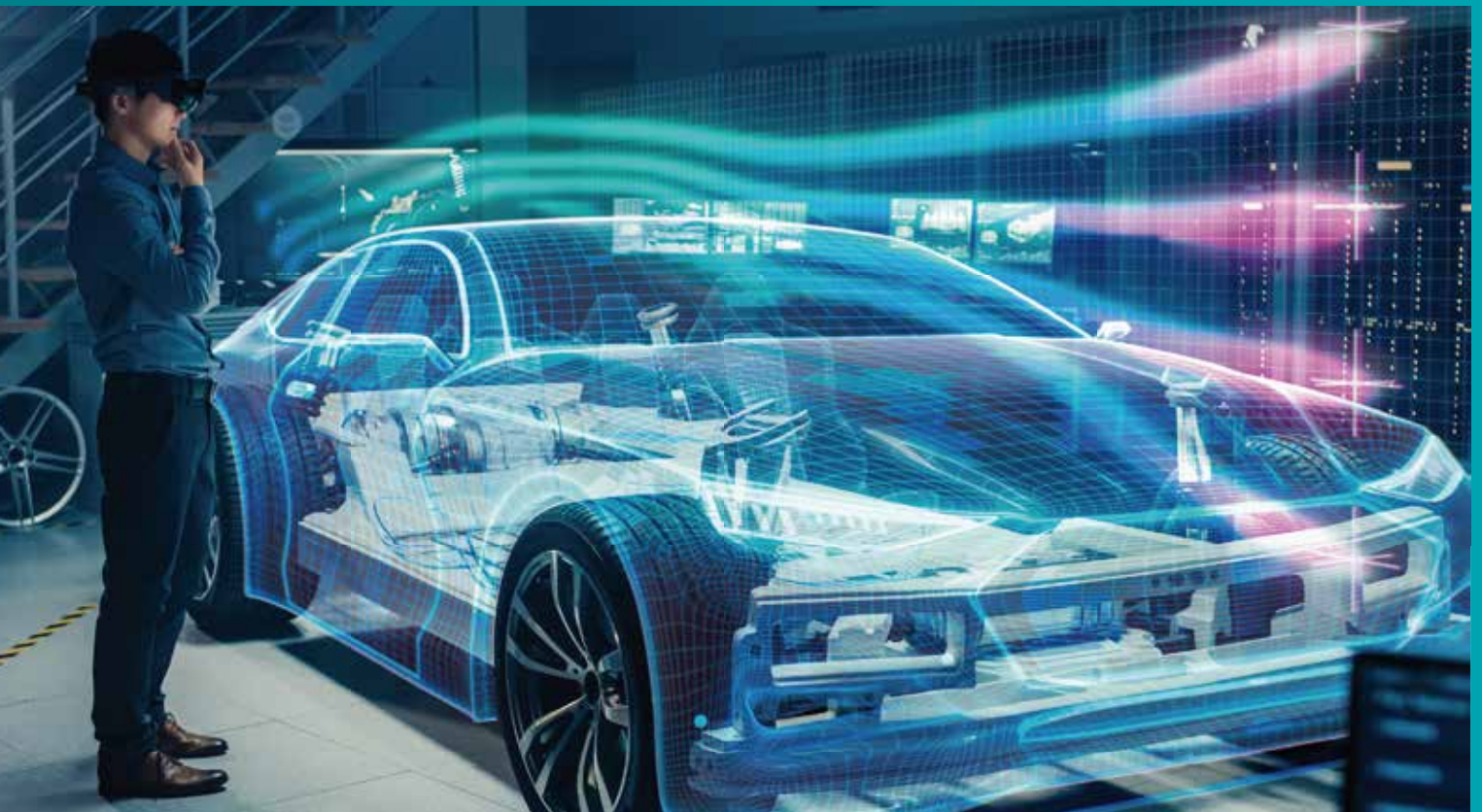
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# POWERING ELECTRIC FUTURES



**Ricardo is working with customers to reduce environmental impact with clean and efficient propulsion solutions.**

We create robust offerings through innovation, advanced systems and cutting-edge tools. Our world-class research and development team defines future technologies to ensure a safe, sustainable mobile world.

We're driving cost out of electrification for original equipment manufacturers. As pioneers of energy efficiency, emissions reduction, and electrification, our developments include thermal management, connected battery management, high power battery packs and ultra fast charging solutions, and digitalising the production of electric and hybrid electric vehicles.

We offer a true end-to-end service - from concept to design to validation and manufacture – creating clean, efficient propulsion systems for the future.

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