Shipping emissions

Ricardo Energy & Environment completes a far-reaching update of the UK’s inventory of shipping emissions.

Ricardo Quarterly Review Q2 2017

A focus on the latest in technology, innovation and sustainability

Interview
Andy Palmer, CEO of Aston Martin Lagonda

Reliable railways
Ricardo PanMon helps prevent costly pantograph failures

Quantum complexity
Ricardo-led programme to develop secure software for failsafe autonomous vehicles
Ricardo puts you first
Motorsport performance that’s in a league of its own

Just as our clients aspire not only to get to the top, but to stay there, Ricardo continues to evolve its expertise and skills in the design, development and production of high-performance transmissions.

Over the past 95 years, Ricardo has been perfecting the art of drivelines and transmissions in the rapidly evolving world of motorsport. Fundamental to our success has been the close cooperation between our customers and our dedicated team of professionals, always putting our customers first.

The results of such a close partnership have been reflected in numerous class and outright victories in the world’s most prestigious endurance races. With transmission technology in every class at the 2016 Le Mans, we continue to assist our customers to master the science behind the art.

Find out how our experts put you first.

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The task of RQ is to highlight the latest thinking in global engineering and technology in the transportation and clean energy sectors and related industries. We aim to achieve this by presenting an up-to-date mix of news, profiles and interviews with top business leaders, as well as in-depth features on programmes – both from within Ricardo and other leading companies.

Client confidentiality is of the utmost importance to Ricardo, which means that we can only report on a small fraction of the work carried out by the company. So we are especially grateful to those Ricardo customers who have kindly agreed to cooperate with RQ and allow their programmes to be highlighted in print: without such help from customers it would not be possible to present such a fascinating insight into the development of new products, technologies and innovations.
The German Parliament has passed amendments to the country’s traffic regulations that will enable testing of semi- and fully-autonomous vehicles on public roads and pave the way for the marketing of cars offering self-driving capabilities.

The amended law allows for automated systems to take over control and for the driver to carry out other tasks, though he or she must always be present in the vehicle and ready to resume control at any time. An onboard black box will constantly monitor the vehicle’s movements and record when and where handovers of control take place.

The legal framework will hold manufacturers liable for any system malfunction and federal transport minister Alexander Dobrindt hailed the technology as the greatest revolution in mobility since the invention of the automobile.

The UK government has authorized a trial of self-driving cars (example pictured) between London and Oxford, and Groupe PSA has formed a strategic partnership with nuTonomy to develop Peugeot 3008 SUVs for driverless operation in Singapore, starting in the third quarter of this year.

Germany gives green light to autonomous testing

After autonomous cars, self-navigating ships, Rolls-Royce is investing heavily in the concept of intelligence for ships in a series of programmes that aim to have a remote-controlled ship in commercial service by the end of this decade. This could pave the way for the first generation of fully autonomous ships in the future.

The company is collaborating with Sweden’s Stena Line on a so-called ‘intelligent awareness’ system, which fuses data from a range of sensors including radar, GPS and the existing AIS (Automatic Identification System). A commercial product is set to be launched later this year.

Rolls-Royce has also announced a strategic partnership with Tampere University of Technology in Finland to develop and test the technology for the support systems necessary for autonomous navigation. This includes an autonomous ship simulator and a shore-based control centre.

Mikael Mäkinen, president of Rolls-Royce Marine, said: “By combining our world-leading capability and knowledge with a clear plan of where we need to go next, we can work with our customers, governments and our global academic research network to develop and bring to market the advanced technology, products and supporting services needed both ‘on-vessel’ and ‘on-shore’, to make our vision of future remote and autonomous ships a reality.”

Norway, meanwhile, is looking towards automated ships and ferries to take heavy truck traffic away from the country’s roads. Double-ended plug-in battery hybrid ferries are already in service on several crossings, and Rolls-Royce is again involved as the supplier of the automatic crossing system, seen as important for overall efficiency on routes where there are strict yearly limits on energy consumption.

Autonomous navigation: Rolls-Royce concept vessel could automate the servicing of offshore installations

Intelligent shipping comes closer

Rolls-Royce concept vessel could automate the servicing of offshore installations
Energy flow charts published by the US-based Lawrence Livermore National Laboratory show that Americans used more renewable energy in 2016 than in the previous year, with solar energy input rising by more than one-third – mainly from large desert-based arrays. Fremont, California, home to Tesla, has mandated solar panels for all new housing, along with preparatory wiring for electric vehicle charging points. For larger facilities in Fremont, the solar arrays will have to provide 80 percent of the building’s electricity requirement, echoing rules in nearby Palo Alto.

The International Renewable Energy Agency has calculated that CO₂ emissions from electricity generation, currently running at 32 gigatonnes per year, could fall by 70 percent by 2050 and disappear completely by 2060. Renewables now account for 24 percent of global power generation.

Next-generation solar cells

Solar cells based on perovskites are among the most efficient, converting more than 20 percent of incident light energy into usable power. Researchers at Karlsruhe Institute of Technology are examining the structures of perovskites at a molecular level to understand the internal transmission mechanisms and, in particular, the role of the alternative ‘nanostripes’ of alternating electric fields.

At Imperial College in London research is underway on a new generation of perovskite cells that will avoid the degradation in performance on exposure to air and light, which means they currently have to be encased in glass. An altogether more radical approach is promised by work carried out by the universities of Antwerp and Leuven in Belgium, which has come up with a device with two chambers separated by a membrane that purifies dirty air on one side and produces hydrogen on the other.

Europe prepares for real driving emissions testing

Against a background of mounting concern about NOₓ emissions and with Europe gearing up for the introduction of Real Driving Emissions testing later this year, new research claims that some 38,000 people die early each year as a consequence of diesel vehicles failing to meet official laboratory-test standards in actual driving. The article, in the scientific journal Nature, said that most of the premature deaths in 2015 were in Europe, but that dirty diesel trucks and buses in China and India were also to blame. With two-thirds of the world’s diesel vehicles designed around European standards, the study also blames European legislation for the problem.

UK-based Emissions Analytics has launched an on-road emissions scoring tool for residents of London and Paris, allowing motorists to better understand the actual emissions of their vehicles in everyday conditions. Data from Emissions Analytics shows that some new cars produce more than 12 times the legal NOₓ limit in the real world.

Fast train from China

The first China-built cars exported to Europe by train arrived at the end of May – a consignment of Volvo S90 models made in Daqing. This marks the opening of China’s One Belt, One Road programme to bring freight weekly via the 12,000 km overland rail route. The 17- to 18-day travel time is twice as fast as transport by sea.

Boosting hydrogen production

Japanese researchers from Kobe and Osaka universities have developed a faster way of producing hydrogen from water. Their photocatalyst is a deliberately non-uniform mesocrystal, able to spatially separate the electrons and electron holes to prevent them recombining, the process which hampers conventional methods.

Charge while you drive

In a potentially far-reaching development, Renault, Qualcomm and Vedeecom have demonstrated dynamic electric vehicle charging using a special 100 m track. At 100 km/h the Kangoo ZE van can absorb energy wirelessly at up to 20 kW.

VW standardizes van safety

Volkswagen has been praised in the commercial vehicle sector for being the first manufacturer to standardize the fitment of autonomous emergency braking (AEB) on its complete range of vans from the car-based Caddy to the large Crafter. AEB has been shown to reduce rear-end accidents by 40 percent.

No air, no punctures

Bike riders could be the first to benefit from new airless tyre technology developed by Bridgestone. The Japan-based tyremaker’s Air Free Concept uses a system of flexible resin spokes stretched along the inner surface of the tyre, eliminating the need for air and making punctures a thing of the past. If feasibility studies are successful, the new tyre could be on sale by 2019.

Geothermal power link

A multinational research project is studying the potential to produce geothermal energy from molten magma rock 2.1 km below Krafla, a volcanic mountain in northern Iceland. The concept could produce five to ten times the energy of a conventional well and, if successful, the power could be transmitted to the UK via a 1000 km interconnector cable.

Search for a name

Automakers often go to focus groups or marketing agencies to find names for new products, but Spain’s SEAT has decided to ask for the public’s help with its new large SUV, due next year. The only stipulation is that the SUV needs to be named after a Spanish place, and voters can submit their suggestions on #SEATseekingname. The winning name will be named after a Spanish place, and voters can submit their suggestions on #SEATseekingname. The winning name will be announced in October.
Cleaner future for trucks

Dramatically cleaner commercial vehicles are in prospect after Tesla founder Elon Musk teased an image of a future electric semi-trailer (right) and Toyota announced a research programme to develop a proof-of-concept hydrogen-fuelled Class 8 heavy duty semi-tractor unit. Last year we reported on Nikola Motor Company’s electric semi-truck project using a hydrogen or natural gas-fuelled range extender motor to enable long-distance operation.

Toyota’s California-based ‘Project Portal’ is assisted by Ricardo [see Ricardo News, Page 24] and is designed to provide the target performance required to support drayage operations in the ports of Los Angeles and Long Beach.

In parallel, Cummins and electric motor specialist TM4 are collaborating on the development of hybrid powertrains for transit buses with inner-city zero emissions capability. The system comprises a gen-set, an onboard li-ion battery, an electric motor on the rear axle, and the necessary fast-charging infrastructure. Workhorse has also released details of its plug-in hybrid pick-up truck and its 460 hp powertrain, UPS is to begin trials with both delivery vans and heavy trucks powered by battery and fuel cell range extender combinations.

In the UK the London Taxi Company will build an electric light-duty commercial van alongside its new battery-powered London taxi, which is currently also undergoing evaluation in New York.

Hydrogen: doubts linger

As Japanese automakers Toyota and Honda continue to invest heavily in passenger car hydrogen fuel cell technology in advance of the very public showcase of the 2020 Olympic Games, there are signs that support for hydrogen fuelling may be softening in Germany.

At a conference in March this year Daimler CEO Dieter Zetsche was cautious about the advantages of fuel cell propulsion. Although the Mercedes GLC crossover will launch as planned in 2018 as a plug-in hybrid with a fuel cell as its range extender, its sale will be restricted to captive fleets with centralized fuelling facilities; instead, said Zetsche, development of electric vehicles will be stepped up as battery costs are falling faster than those for fuel cell systems.

At present the lack of coherent hydrogen fuelling networks in all but Japan and California is a major brake on the prospects for fuel cell passenger cars. Toyota, say commentators, is taking a very long-term view in the belief that fuel cells will eventually beat batteries on costs. Toyota has a partnership with BMW on battery, hybrid and fuel cell technologies.

The new age of sail

Against a background of tightening marine environmental standards from 2020, shipping operators are beginning to evaluate options for saving on fuel costs and reducing noxious emissions from their fleets. Eco Marine Power of Japan has for some years been promoting its Aquarius system of rigid sails and solar panels, and now Royal Dutch Shell and Maersk are to trial a rotor sail solution (pictured) developed by Finland’s Norsepower. Fitted initially to a 245 m tanker, the twin 30 m high carbon fibre rotary sails spin about vertical axes to create a pressure differential which provides forward thrust to help propel the vessel and allow the main engines to be throttled back. The devices are expected to save up to 10 percent in fuel costs, representing a good rate of return.
Shanghai sparks electric interest

Encouraged by government incentives, China’s market for electric vehicles is comfortably the world’s largest, expanding rapidly to reach an expected 800,000 units in 2017. April’s Shanghai show produced a rash of automaker announcements, with Volkswagen confirming it would launch a volume EV in 2019 with a 600 km range and costing the same as a diesel model. The German company will triple its investment in EV development, said CEO Matthias Müller, with a promise to spend some €9 billion by 2022 and launch a range of low-cost EVs in China.

BMW CEO Harald Krüger, pledging to sell 100,000 electrified vehicles this year, predicted that with faster recharging systems soon to appear, range would no longer be a differentiating factor between competing electric models. Honda’s Clarity EV seems to bear this out; its stated range (on the US drive cycle) is just 130 km, whereas its PHEV companion manages under 70 km in battery mode.

Chinese electric models hoping for a share of the glamour include NextEV’s No EP9 sports car, claiming a 427 km range and a recharge time of just 45 minutes, and the seven-seater ES8 SUV with a swappable battery system.

Audi’s material mix

The new Audi A8 to be released this summer will grab headlines with its advanced autonomous features, but it is an innovator in terms of its construction, too.

No fewer than 29 different materials are employed, along with 14 joining processes. The result is a body shell 12 percent lighter than its predecessor’s, as well as 23 percent better in torsional rigidity. A major contributor to this rigidity is the innovative use of a large carbon fibre composite panel between the back seats and the trunk: this is bonded in during final assembly and adds 33 percent to the overall rigidity.

Aluminium makes up the bulk of the components in the space frame structure, though high-strength steels are used for the sills and A- and B-pillars. A magnesium triangle braces between the strut towers and the engine bulkhead.

Automotive cyber security: a real, present and growing challenge

Eric Chan – Ricardo global technical expert on connected and automated vehicles

These days, we take it as read that computer systems need to be protected against online threats, and the term cyber security is very much a part of everyday vocabulary; cyber crime is now criminal big business, costing the UK an estimated £30 billion annually. But the recent global ‘WannaCry’ worm provided yet another sobering reminder that we are still a very long way from achieving true security even in comparatively mature and mission-critical business IT systems. Perhaps of even greater concern is that the scope of the devices and systems that we need to protect is expanding at an increasing rate, as the ‘internet of things’ gives us all manner of internet-connected devices, from domestic central heating to white goods.

Connecting everything together, however, brings the risk that one compromised system will be used as a gateway to other. Confidential and potentially valuable data can thus be placed at risk on any other device connected to the same network, either full-time or on an occasional basis, from smartphones, home Wi-Fi routers, and network disk drives to PCs.

Few consumers may be aware, but this list of internet-connected devices already includes our cars. Many new models are connected over the air for telematics and maintenance, for safety systems such as eCall, by consumers using insurance-based monitoring technology, and by the many smartphone apps available to consumers.

The most obvious motivation for the hacking of automotive systems is for theft of the vehicle itself, and there have already been instances of thieves taking control of key encryption through the use of pirated software and exploiting vulnerabilities in security systems. This could take the form of radio ‘amplification’ attacks to spoof keyless entry systems, for example.

Beyond theft of the vehicle, other criminal motivations for hacking include the theft of personal information from payment systems, accessing data from onboard sensors such as cameras and lidar, taking control over vehicle functions perhaps in the manner of a ransomware attack, or using the vehicle as a compromised gateway into other connected systems.

The need to provide cyber security for the vehicles we own and operate is thus a crucial and growing imperative. Cyber security must in my view be considered during the design phase, as adding it on afterwards will never be as effective. This represents a major challenge for vehicle OEMs to transition their legacy vehicle architectures, ECU’s, and development processes to take into account these new requirements. There are strong links between methods and approaches required in the development of functional safety and cyber security, offering opportunities to us for early progress. But there are important differences too. For instance, while the threats protected through functional safety remain constant through the life of the vehicle, cyber security is an ongoing war of attrition against constantly innovating criminals who will have access to new data and tools over time.

The need to provide cyber security for vehicles is a crucial imperative. Cyber security must be considered during the design phase: adding it on afterwards will never be as effective

Fifty years ago, not least prompted by the efforts of campaigners such as Ralph Nader, the auto industry realized the need to place safety at the forefront of design, and in the 20 years since the advent of Euro NCAP, no one questions the need for safety any more. What we need now, in my view, is the same focus upon automotive cyber security – and this is one of the primary reasons for Ricardo’s participation in the S*Star5 programme (see Ricardo News p25) which will address the increased threat from cyber security with the proliferation of connected and automated road vehicles.
The beginning of April saw the opening of your latest factory at St Athan in south Wales. Why did you choose that particular location?

We made it clear from the outset that the decision would be made on three factors: quality of site, labour and transportation – the cost of parts, bringing them into the country, of processing and logistics. If, say, you’re selling principally to US customers it might be cheaper to manufacture in the States. So we looked at where’s the balance of our customers for this car, and where’s the best place to locate it. And the ability to launch the car in 2019.

We evaluated 20 different sites. If you looked purely at the grant aid, then nothing in the UK came close to some of the places we were considering. Eastern Europe offered really good incentives, but the ability to recruit labour and the supply chain challenges... when you balance all of those, that’s where Wales came out top.

I was struck by the size of just one St Athan hangar, and you’ve got three to fill. Is that because you have greater ambitions beyond the Second Century Plan we already know about?

Our Second Century Plan goes beyond the DBX crossover, for sure: you’ve got the two Lagondas, so all our large car platforms will be built there. We’re laying a factory out knowing that bigger and smaller cars can be manufactured there. There will be at least three cars. Plus, the ability for our Gaydon headquarters to supply some parts for St. Athan and vice versa. I don’t have a plan beyond those three cars, although it might evolve in that direction. My first objective is how can we fill the capacity that we’re creating. The site is bigger than Gaydon.

Could V12 engine production migrate back from Cologne to the UK?

All the manufacturing equipment is in Cologne, so it’s not an immediately obvious solution to move it. There are some financial advantages to help balance matters out having exposure to the Euro zone where we sell cars.

Following Brexit and the drop in Sterling, as a circa 80 percent exporter that’s no bad thing at the moment. I do need to think more about currency exposure as we become more of a global company, which is why we refinanced a significant proportion of our debt in dollars as a natural hedge.

In the light of the recent ransomware attack it was prescient of you to highlight cyber security as an ‘arms race’. Can you expand on that?

I probably referred to autonomous driving as an ‘arms race’. Lots of OEMs are playing catch-up with Tesla: Daimler and Nissan are dominating, and billions of dollars are being spent in individual companies, not just by the industry, trying to get (SAE) Level Three into the market in 2020.
Firstly, I don’t have that time pressure – Astons don’t lend themselves to autonomous driving. There is a future-proofing factor we need to address when it comes to Lagonda, cars which are more likely to be chauffeur driven – but I don’t have to do that by 2020. My fear is that the industry is creating a new opportunity and an increasingly fragile infrastructure to allow cyber hacking. Historically, the industry has never been very good – even when it comes down to theft, which has bitten me painfully a few times in my career. I think we should find an industry protocol for cyber security: Aston Martin Lagonda (AML) can create its own capability as a level of specialism and maybe others can use that as well.

You also described St Athan as a centre for EV motors and battery production. Are you implying AML will make its own rather than work with partners?

It will be a combination: it could be as simple as bolting various supplier units together. We won’t make our own battery cells, but we could assemble them into the pack, for example. Arguably, we could develop our own motors: we’re in the process of sourcing electrical components for the Rapide programme right now. That, to some extent, will determine how much space we set aside for our EV.

Will electric machines take over from combustion engines in sports cars like Aston Martins, or are they more suited to luxury sedans and crossovers and the Lagonda brand?

Ultimately, EVs are more suited to a certain kind of mission rather than a certain type of car: what EVs don’t really like are extreme temperatures, going really fast or travelling uphill. What they do like is constant temperature, slow to medium speeds and a regular pattern – ideal for urban environments. It’s more to do with the customer mission rather than the segment the car is in. We’re on the Moore’s curve now and EVs’ ranges will be extended as we go to the next generation batteries and, maybe, solid state. I am a great believer in EVs and I think it’s fair to say, although my colleagues might not agree with me, that by 2025 EVs will be 25 per cent of the market.

Will you have to have some sort of hybridization, in the broadest sense of electrification, by 2025 for AML to meet CO2 legislation?

We made a conscious decision to continue developing, and offering, the V12. To make that happen we need a big offset, which is why we have chosen to go with battery-electric; we will hybridize some or all of our petrol engines. We won’t go diesel, plug-in hybrid or even hydrogen. Hydrogen is interesting from an engineering perspective but infrastructure investment is enormous, so unless there’s big government funding you will never nurture the technology – it was hard enough with EVs.

“I don’t think Gen Z has fallen out of love with the car: I think they’ve fallen out of love with the fact that it doesn’t represent the freedom it once did”
What’s the secret of utilizing your relationship with AMG and still retaining the core values of both marques? Daimler owns five percent of the company and in return AMG provides us with a V8 and Mercedes-Benz supplies our electrical architecture. We make everything else ourselves, so Daimler-AMG is not that different from any other supplier. Purity comes with our V12. The V8 is shared with AMG: we engineer it into our cars in a unique way, we change the sound, throttle response, it’s mounted lower in the chassis, and the character is ours, even if the internals are unchanged.

You, and the rest of your team, must be looking at where and what AML will be producing in 2030 and beyond. What do you see in that crystal ball? Our 2015 business plan runs through to 2022, relatively speaking a longer outlook than most OEMs that look at six years maximum. We’re at seven. The fifth project after DBX is the mid-engined sports car, which is why I brought Max Szwaj from Ferrari as he has experience of developing mid-engined architecture. Sixth and seventh cars are both Lagondas, which is challenging Marek Reichman’s design team – how do we do these without affecting Aston?

What about the further future? We have some eye on what might be future technologies, mainly focused around powertrain. And trends like ride-sharing – we need to ask ourselves whether that will ever happen and how would it work in our luxury space. There’s an increasingly heated debate within the company about car sharing or the automotive equivalent of Airbnb. I am pushing the company down the path of increased personalization, which flies in the face of sharing. Some colleagues argue that underlying trends will impact on us, even if it’s people buying into car clubs rather than owning their own supercar.

Lastly, I don’t think Gen Z has fallen out of love with the car. I think they’ve fallen out of love with the fact that it doesn’t represent the freedom it once did. The industry has to reinvent the car for Gen Z: future cars have got to be propelled by the automotive OEMs rather than being led by smartphone technology. Cars have to be part of the solution, not the problem.

Dr Andy Palmer, president and CEO, Aston Martin Lagonda
Dr Andy Palmer began his career as an indentured apprentice and graduated from Warwick University with a Masters in Product Engineering in 1990; his doctorate in Management came from Cranfield University in 2004.

Prior to joining Aston Martin in 2014, Palmer held the post of chief planning officer at Nissan Motor Co and was a member of the Nissan Executive Committee. He held a number of senior positions during his 23-year career with Nissan, including roles in corporate planning, product planning, marketing, sales & IT leadership. From 2011 he served as chairman of premium brand Infiniti.
Pollutants and greenhouse gas emissions from shipping form a significant part of the overall air quality picture and are now included in national and international reporting obligations. Surrounded by some of the world’s busiest shipping lanes, the UK is a particular focus, and Ricardo has been commissioned to deliver a comprehensive update of the shipping emissions inventory for the UK National Atmospheric Emissions Inventory. Tony Lewin reports.

The 2015 Paris Agreement on Climate Change, reinforced a year later at the climate summit in Marrakech, has been the starting point for significant additional moves to help limit international greenhouse gas (GHG) emissions. At the highest strategic level, some 200 nations agreed to measure, report and verify their emissions of GHGs: by cataloguing emissions from activities such as industry, agriculture, power generation and transport, countries establish their individual national GHG inventories, the first step towards applying targeted reductions. Ricardo Energy & Environment has been involved in such strategic initiatives for many countries.

On a more detailed level, Ricardo’s work also includes running the UK’s National Atmospheric Emissions Inventory (NAEI). Although the inventories that countries have to report under the Paris agreement do not need to include international shipping, for some nations – especially island states such as the UK that are on busy shipping lanes – the reporting...
of purely inland sources is insufficient to provide a complete picture of atmospheric pollutants. Such is the intensity of shipping around Britain, through the English Channel and around some UK ports, that emissions that occur at sea are likely to have a significant effect on air quality in coastal communities on land; they can make a sizeable contribution inland too.

Under present agreements the UK has to report domestic shipping emissions in its national inventory, but chooses to report an estimate for international shipping emissions as a ‘memo item’ which is not subject to policy controls. Related programmes such as CLRTAP (the Convention on Long Range Transboundary Air Pollution), the National Emissions Ceiling Directive and the UK annual carbon budgets have focused attention on the need to encompass all significant emissions sources, including shipping.

However, although existing inventories of shipping emissions are reasonably detailed, they do not cover several important classes of shipping activity. What more, levels of shipping activity are forecast to rise significantly in the coming years as global trade expands. For these reasons, therefore, Ricardo Energy & Environment was commissioned by the UK government to undertake an update of the shipping emissions inventory component of the NAEI.

The NAEI explains Tim Scarbrough, principal consultant at Ricardo Energy & Environment, is a high-level strategic tool for local air quality modelling. Ricardo’s analysis, in conjunction with project partner University College London Consultants, has addressed several drawbacks to the existing maritime inventories – principally that they were based on estimated rather than actual routes taken by ships, that they did not take account of variation in vessels’ engine loads or speeds, and that they failed to capture certain types of craft, especially fishing vessels, offshore fleet and service vessels.

The Automatic Identification System (above) tracks the positions, courses, speeds and draught of vessels. Cross-referencing with technical databases allows accurate prediction of each ship’s emissions at three second intervals.

Reviewing the available options, Ricardo and its partners opted for an entirely new methodology relying on AIS (Automatic Identification System) data from the UK’s Maritime and Coastguard Agency. AIS uses VHF radio signals to report vessels’ positions and identify them. The AIS messages are sent up to every three seconds, and the messages are received directly by other vessels and by the AIS receivers operated by the UK Coastguard. AIS messages also provide additional information on the speed of the vessel among other parameters. This, says Scarbrough, enables very precise plotting of ships’ courses and speeds.

The new categories include:
- Bulk carrier
- Chemical tanker
- Container
- General cargo
- Liquefied gas tanker
- Oil tanker
- Cruise
- Refrigerated bulk
- Roll-on, roll-off
- Yacht
- Service tug
- Miscellaneous – fishing
- Offshore

This makes it a vital tool for local air quality modelling.

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with the high degree of granularity that is essential to understanding the effects of maritime emissions on the air quality of coastal cities such as Southampton. One year’s worth of stored AIS data was used.

The ships’ identities are then cross-referenced to a register of world shipping. The register contains a host of detail for the majority of the world’s registered vessels over 100 gross tonnes, giving technical information on each vessel’s engines and performance characteristics.

Marrying the two streams of data together, says Tim Scarbrough, enables the model to predict with a high degree of accuracy the emissions of any AIS-tracked vessel at any given speed and load condition; even when in port or at anchor, the emissions of the ship’s auxiliary engines and boiler are accounted for.

Adding to the magnitude of the challenge was the inclusion of many more classes of vessels, notably offshore service vessels, passenger ships and fishing boats, many of which were poorly covered in earlier studies.

The only drawback of this approach is the enormous amount of data that it generates. “One year’s data for all the vessels around the UK, each reporting up to every three seconds, resulted in more than 2 billion data points,” notes Scarbrough. “We had to thin these down to around 100 million, but it was still a considerable data processing task.”

**Accurate estimation of selected pollutants**

The present model confines itself to predicting the emissions to air of greenhouse gases (CO₂, methane and nitrous oxide), sulphur dioxide, NOₓ, particulate matter, carbon monoxide and volatile organic compounds (VOCs). No attempt is yet made to quantify fugitive emissions of refrigerants – although this is believed to be negligible compared to the greenhouse gases included. Emissions to water – for example as ships flush out their tanks – could later be of interest, though this would demand a very different methodology.

The complex exercise will not need to be repeated: the 2015 snapshot has so much detail and so many layers that it can serve as a starting point to model future forecasts as well as a basis to “back-cast” to earlier years to gain greater understanding of emissions phenomena. As Scarbrough explains, the official national emission inventories also require estimates of historical emissions, domestic shipping included.

“We will be able to estimate previous years – and future years – by comparing it to this base year”, he says. “The way that we do this is to look at the three main variables affecting emissions that have changed over time: how many ships are operating, what their fuel type is, and changes in emission factors over time as engines themselves have improved. We make indices for these three things, and this allows us to back-cast. The main thing is the activity driver, and for this we use statistics published by the Department of Transport for each vessel type, for example, or the number of tonnes of cargo from each vessel type landed in the UK for each year.”

So while there is no historical time series that can be projected forward into the future, estimates can be made for the average annual growth or contraction for each individual vessel category. These, overlaid with estimates of the improvements in engine efficiency over time and changes in the fuel type driven by legislation, can be used to generate forecasts for future years.

**Predicting the emissions**

The Clarksons World Fleet Register database employed by the inventory project contained technical detail on tens of thousands of the world’s registered vessels operating internationally or domestically.

Position, speed, vessel size and draught information provided by AIS is overlaid on these specifications to give an accurate prediction of the emissions of each of those ships between each AIS message, using the speed and draught data to infer engine load conditions.

The database holds details of vessels’ main engines, but additional estimates for the auxiliary engines and boilers have been made so that emissions can be predicted even when the ship is manoeuvring, moored, or at anchor.

A full year’s dataset contains details on more than 100 million data points, each matched uniquely to the database of vessels so as to give a complete record of each ship’s emissions over the year.

**The environmental picture**

The Ricardo maritime air quality work comes in the context of growing international concern over pollution at sea, be it in the atmosphere or in the water. Ricardo’s water practice offers expertise on monitoring port water quality for environmental permit compliance, while on the engineering side of the business Ricardo specialists in large marine engines are working at the forefront of technical developments.
Firmly in focus among all concerned are the steadily tightening controls on international shipping and marine fuels. A sulphur emission control area (SECA) is already in force across the North Sea and English Channel, following the lead set by the Baltic in 2005; most of the US east coast, along with parts of the Canadian coast and the Caribbean also control fuel sulphur content. Tighter NOx controls on new engines, depending on the vessel’s engine rpm, are in force for large vessels within 200 nautical miles of the US coast and will apply to new ships built from 2021 operating in the North Sea and Baltic. This is expected to lead to increases in the use of exhaust gas recirculation in engines, or the use of selective catalytic reduction as an end-of-pipe measure – or the use of alternative cleaner fuels such as LNG.

Fuel is a particularly contentious issue, with MEPs calling for the International Maritime Organisation (IMO) to implement a ban on traditional heavy fuel oil (HFO) in the Arctic. HFO has already been banned in the Antarctic and there are fears that the accelerated melting of the ice in the northern polar region will allow an opening up of new shipping routes and thus a further twist in the pollution spiral.

Greenhouse gas emissions, largely in the form of CO2 and methane, are a global rather than regional or local issue. A comprehensive study of maritime GHG emissions published by the IMO in 2014 concluded that shipping contributed around three percent of global CO2 emissions on average between 2007 and 2012. Fluctuations over this period are related to the effects of the 2007-8 financial crisis, which led to the widespread adoption of slow steaming – down to as low as 60 percent of design speed in some cases. Slow steaming, while reducing real-time CO2 emissions by as much as 27 percent, means more days at sea and masks an effective fleet over-capacity.

Either way, however, the existence of a comprehensive spatially resolved inventory such as that developed by Ricardo and University College London provides a sound basis from which to model future scenarios and policy options such as speed restrictions, fuel...
improvements and mandatory itineraries in sensitive areas.

**Expansion and outlook**

Given the success of the inventory capture rate around the UK coast and through the English Channel, a natural next step would be to extend the scheme further afield. The reach of the data gathering is effectively only limited by the range of the terrestrial AIS signal, and the use of satellite AIS data could potentially be added to widen the system’s operating radius. Already, the system estimates emissions for the UK fishing fleet even after these vessels travel a long way out of terrestrial AIS range before returning to land their catch in the UK; emissions for the whole trip can be calculated and included in the overall inventory.

Nevertheless, counsels Tim Scarbrough, the very high spatial resolution of the data makes it much more relevant to studying air quality effects at a local level.

Whether the discussion is macro or micro, however, the multi-layered emissions inventory will be a very valuable resource on a technical level and also from a planning perspective. Future environmental measures could be modelled and their effects predicted with some degree of confidence; this could be done relatively simply by changing some of the assumptions in the existing forecasting models.

Forecasts have already been completed as far as 2035 to model the effects of projected changes in shipping activity, transport efficiency, fuel types and emission factor improvements. However, it is not possible to anticipate structural or route changes or cater for their effects, and while work is still in progress no quantitative data can yet be released.

Yet one thing is abundantly clear. Despite the greater coverage of smaller craft, such as tugs, service vessels and passenger ships that are now included in the emissions inventory, as far as the UK is concerned it will still be the bigger vessels that are the dominant source of emissions. And in contrast to domestic traffic, which has remained roughly level since 2009, international movements are on an upward trend.

“The big vessels are really the problem,” says Scarbrough. “They consume vast amounts of fuel, even though there are fewer of them; but that doesn’t mean that the other categories are not important. As an island nation with an active offshore energy market, we have a lot of passenger vessel movements, as well as offshore service and fishing boats that are an important part of the UK inventory.”

According to IMO estimates, shipping accounts for between two and three percent of global man-made CO2 and, even in 2011, when the world economy was still recovering from the financial crisis, international shipping consumed four-fifths of the 254 million tonnes of fuel sold to the industry; domestic shipping was far from negligible at 40 million tonnes. The IMO has put into place efficiency improvement measures for categories of shipping responsible for 85 percent of maritime CO2 emissions, but even on a business as usual basis the same organisation forecasts that, by 2050, CO2 from shipping could have grown by between 50 and 250 percent to as much as 2,500 million tonnes a year – which gives a chilling idea of the scale of the problem.

Position density of shipping around the UK – AIS Class A

Data generated for the shipping emissions inventory shows clearly the concentrations of movements around the UK’s major ports and through the English Channel and off the coast of Cornwall in the south west. Also clearly identifiable is the frequent service traffic to and from the offshore installations in the North Sea, with oil and gas fields in the north and offshore wind farms further south.
The PanMon pantograph monitoring system has been developed by Ricardo Rail to improve the reliability of electrified routes and protect critical infrastructure. It is already approved by Network Rail in the UK and under evaluation by InfraBel in Belgium, as Anthony Smith reports.
Electrification has been fundamental both to new railway development and the improvement of existing lines across the UK and continental Europe for many decades. With significant benefits in both operational efficiency and environmental impact over the alternative of diesel traction (see panel), this trend is entirely understandable.

The favoured electrification solution, especially where higher speeds and longer distances are involved, is via high-voltage overhead line equipment (OLE), where trains pick up their power through roof-mounted pantographs with contacts that slide along the underside of an overhead contact wire. The crucial interface in this system is that between the pantograph and contact wire. Poorly maintained or damaged pantographs are a significant cause of so-called ‘dewirement’ incidents, in which...
Anatomy of overhead electrification

At the heart of the OLE system – which also comprises the supporting steelwork masts and gantries, and tensioning wires known as the catenary – is the ‘contact wire’, which provides the continuous power supply to the rolling stock. This critical component is tensioned in lengths of around 1.5 km, and follows a zig-zag pattern or ‘stagger’ between the support masts which are spaced at around 50 m intervals.

Power is collected by pantographs by means of a series of carbon strip inserts that slide along the underside of the contact wire. These are consumable items, which need to be replaced on a planned inspection and maintenance cycle. The wire’s stagger ensures that the contact patch on the pantograph moves from side to side as the train moves forward, thus ensuring that the wear is an even as possible across the carbon strips.

As well as providing the physical contact between the train and its electrical supply, the pantograph also transfers considerable power across this contact patch. To put some numbers to this, in the UK the standard operating voltage of the contact wire is 25 kV AC. At this voltage, the pantographs of an electrical multiple unit commuter train might each draw up to 2 MW, while that of a high-speed train such as a Pendolino – where just a single pantograph is typically deployed for each service – could typically draw up to 6 MW.

Snagging can cause extensive damage to the electrification infrastructure; although comparatively infrequent, these incidents can lead to extensive and costly disruption to rail services.

To help tackle this issue, Ricardo engineers have developed PanMon, an innovative system that uses highway enforcement (speed-camera) technology to continually monitor the pantographs of passing trains, automatically identifying incipient problems and providing real-time warnings to enable immediate corrective action and targeted maintenance. In this way, pantograph problems can be resolved before they cause serious and costly consequential damage to the electrification infrastructure.

**Pantographs: the critical interface**

The interface between the pantograph and the high-voltage contact wire is thus crucially important, not just for the individual train but for the reliability of the complete OLE system. Pantograph faults are a major cause of dewirements, where snagging of the sliding carbon strip or supporting structure can lead to catastrophic damage to sections of the OLE. While robust and resilient against extremes of weather and normal service operation, OLE systems are necessarily slender and light weight in their construction, such that the momentum of a speeding train can do a significant amount of damage over a lengthy section of track – in the worst cases, tearing down almost the entire system other than the steel masts.

The financial consequences of this type of damage can be extremely costly, as Ricardo Rail’s business manager for intelligent rail, David Bishop, explains: “In the Netherlands we see around ten dewirement incidents per year, and on the UK’s Network Rail system, around one per month. Each of these costs the industry around £1m on average, but on high speed lines or at major bottlenecks, the situation can be much worse.”

In particular, Bishop cites the examples of a dewirement on the mainline spur tunnel at Heathrow airport in 2016 which was attributed as costing over £1m, while one at Retford on the UK East Coast Main Line earlier in 2017 reportedly incurred £2.5m costs in ‘performance regime’ payments alone (the rebate paid to train operators in lieu of infrastructure-related delays).

For this reason, a system that can provide early warning of the conditions that lead up to dewirement will be of major value to the rail industry worldwide.

**Hub of rail innovation**

The Utrecht-based operation of Ricardo Rail is one of the consultancy’s principal technical facilities, employing over 200 railway engineers and technical specialists in teams ranging from rolling stock procurement to railway operations and maintenance support. A wide range of services is provided – in particular to the Dutch state railway, Nederlandse Spoorwegen (NS) – which gives the local Ricardo Rail team valuable insights into the challenges of railway operations. When this is combined with such operational knowledge and expertise of the entire group, such operational knowledge can be the feedstock of extremely useful product innovation.

“In the Netherlands, Ricardo Rail has a team that is called upon to investigate the root cause of incidents such as derailments or OLE dewirements,” explains Ricardo Rail technical consultant Arjan Rodenburg, who is leading the development of Ricardo’s smart pantograph monitoring system, PanMon. “The task of this team is to identify the conditions that led to each incident and to help the customer with advice both on immediate repairs as well as potential preventative action for the future.”

Through this work, we acquire first-hand knowledge of the problems that face train operators and infrastructure managers.”

In terms of OLE systems, Rodenburg’s colleagues identified the extremely costly consequential damage that can arise due to dewirement incidents, and the fact that the root causes of the majority of these are attributable to pantograph failures. All of this led to the idea behind the Ricardo PanMon pantograph monitoring system.

**Smart monitoring idea**

As with many successful monitoring innovations, PanMon represents a combination of existing sensing equipment with cutting-edge data analytics and artificial intelligence, to provide a powerful and intuitive new system for rail operators and infrastructure managers to help identify and mitigate these risks.

The system monitors the pantographs of trains as they pass along the electrified section, using photography and data analytics to provide early warning of conditions that lead to dewirements. For example, the PanMon system will automatically flag conditions that put the sliding carbon strips at risk of damage, enabling operators to take immediate action.

The analysis capabilities of PanMon will automatically flag pantographs at risk of damaging overhead line equipment.

High speed photography of a Pendolino train passing a PanMon installation (above, right). The analysis capabilities of PanMon will automatically flag pantographs at risk of damaging overhead line equipment.
technologies, together with smart analysis software, and real-time processing and reporting. “One of my colleagues came across Sensys as a company that had a camera system to capture high speed images of pantographs,” continues Arjan Rodenburg. “The problem was, that while these provide an instantaneous shot of the condition of a given pantograph at a given location, detailed visual inspection of each image would be excessively time consuming. As such, there would be only a very remote chance of being able to identify a failing and potentially damaging pantograph with sufficient speed and efficiency to be able to take preventative action.”

The Sensys camera system is fitted to a gantry immediately above the running rails and contact wire, and takes high speed digital images of each pantograph from above as it passes. The concept of PanMon is based on the use of smart software to very rapidly capture and process the images and, based on continuous learning, to characterize the condition of each passing pantograph.

In addition to its Sensys camera, the PanMon system also uses a high-speed video camera provided by DMA of Italy. This is mounted at pantograph height on a mast alongside the rails, and captures the uplift of the contact wire as each pantograph passes, using LED lights to illuminate the video sequence. Finally, in terms of PanMon’s sensing systems, a tag reader identifies each carriage of each train passing, such that any fault can be immediately traced back to a given vehicle and individual pantograph.

**Automatic analysis**

As a PanMon installation captures its high-speed photography and video of each passing pantograph, the first automatic processing task carried out by the system is to correct for the perspective and view angle of the camera, so that an orthogonal representation of the pantograph can be constructed from the image. This is then compared by the software against a library of types and designs of pantograph that are known to pass the location. The system then assesses the image for physical damage such as broken or bent structural components which might pose a risk of snagging the contact wire or catenary. Damage such as this can occur as a result of acts of vandalism where foreign objects become lodged in the DLE system, or where maintenance equipment has been erroneously left in place. While such initial damage to the pantograph may have been isolated, PanMon can identify immediately if there is a risk of consequential dewirement – for example, at a junction or points switch location where the train crosses between lines.

In addition, PanMon automatically assesses the wear on the carbon strip inserts of the pantograph. Here the system looks both for the general level of wear – for example, whether replacement should be considered at the next planned depot inspection. More importantly, however, it identifies whether any localized damage has occurred in the form of chipping, which might risk snagging the contact wire as the contact patch moves from side to side as a result of the stagger pattern, or at junctions.

Finally, the video captured is analysed for the uplift of the contact wire as the pantograph passes and for its dynamics as the wire settles following this. Pantographs generally apply upward force either through a spring-loaded or pneumatic system, or a combination of both. In addition, some are equipped with aerofoil sections that add to the contact efficiency, resulting from superior fuel efficiency
- Quieter and zero emissions at point of use – particularly advantageous in the urban environment
- Superior performance as a result of higher power-to-weight ratio, which allows them to accelerate and brake more quickly

While low-voltage DC third-rail systems (typically operating at 600-750V) offer advantages for some underground, metro and suburban networks, this form of electrification is restricted both in the efficiency of electrical supply, and a maximum operating speed of around 110 mph. As a result, almost all new mainline electrification is provided via high-voltage AC overhead systems, in the UK operating at the standard voltage of 25 kV.
force. Contact wire uplift might be as high as 120 mm and will depend upon train speed and prevailing wind conditions as well as the condition of the pantograph. PanMon can be programmed to take account of such local conditions, and provide warnings if the uplift exceeds the design limit of the OLE.

**Advance warnings**

Fault notification from a PanMon installation can be provided in almost real time, with some installations using the mobile 4G data networks while others communicate directly with the customer railway’s wired communications networks. In either case, PanMon’s warnings can be set to specific levels depending upon the damage identified. In extreme cases where there is an imminent risk of dewirement occurring, the network control centre might be alerted to halt a train showing a fault at the next opportunity, either withdrawing it from service, lowering the offending pantograph of a multiple unit train, or switching pantographs for a high-speed train.

Conversely, less severe damage or excessive wear might instead merely be flagged for that pantograph on the next scheduled maintenance operation for the train in question.

**Customer interest**

The UK rail infrastructure operator Network Rail was the first customer to recognize the potential of PanMon to deliver reliability improvements and cost savings, as David Bishop explains. “With the financially-driven nature of a privatized railway, the business case for an innovation such as PanMon is comparatively easy to demonstrate. Each delayed or cancelled service accrues significant financial cost to the infrastructure manager, and dewirements are typically very costly due to the large number of services affected by each incident, and the time taken to fix the OLE and restore normal service.”

Following an initial installation at Cheddington on the West Coast Main Line (WCML), Network Rail formally approved the use of PanMon for use across the whole UK national rail system – a highly significant step as PanMon remains the only such system certified for use by a major network operator.

Orders have already been placed for two PanMon systems to protect the Heathrow airport spur at the entrance and exit tunnel portals, underscoring the particular attraction of using a system such as this to protect critical infrastructure where service disruption would be particularly costly.

Beyond the Cheddington installation, where a further three units are earmarked for the three tracks not currently instrumented, a further pair of four-track installations have been identified for the WCML route, with potential further applications on many other UK electrified mainlines.

In Brussels, the Belgian state railway operator, Infrabel, is in the process of evaluating a system with a view to its eventual certification of PanMon for the national network. Current work is ongoing in developing the software-based library of pantograph types and fault analysis to capture the requirements of the Belgian rail system.

“PanMon is effective for all vehicles using pantographs, from international high-speed trains travelling at 340 km/h to city centre trams,” explains Bishop. “Damage to pantographs and contact wire is most likely to be serious for trains travelling at speeds above 80 km/h, and the consequences are most costly on the busiest of routes. As such, the optimum locations for PanMon installations are likely to be in the protection of ‘golden assets’ such as major junctions and system bottlenecks, or key locations. The order already received for the tunnel portals into and out of Heathrow airport demonstrates just that.”

**Future OLE monitoring technology**

If PanMon provides an instantaneous health check and emergency warnings regarding the state of every pantograph passing a given location, a further Ricardo Rail smart monitoring innovation is under development aimed at assessing the condition of the OLE. The CatMon system comprises a range of sensors fitted to an individual pantograph, which continuously feeds back data regarding the contact wire. Chipping of the carbon strips of pantographs is thought to occur most frequently at so-called ‘hard spots’ where the flexibility of the contact wire changes sharply. This can be, for example, at insulator sections, or at junctions.

Rolling stock equipped with CatMon will thus be able to report back, in real time, the location of hard spots or excessive contact wire flexibility, enabling OLE maintenance to be more proactive in targeting locations that might be either at risk of failure themselves, or having the potential to damage pantographs and hence lead to dewirements in other parts of the network.

“Ricardo has something of a unique position in the international rail sector in that our engineers have detailed asset knowledge of both rail rolling stock and infrastructure systems as well as railway operations,” concludes David Bishop. “PanMon and CatMon are just two among a range of innovations that we are developing and making available to customers, based on the generation of real-time condition monitoring and analysis. Collectively, these intelligent railway systems can help rail infrastructure and operations businesses to manage safety-related risks in real time, and to develop improved asset management and cost-effective maintenance processes. In this way, we are able to make a significant contribution in improving railway performance while driving down costs.”

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**Pantograph innovation**

![Diagram of Pantograph Innovation](image-url)
Something is happening within the automotive industry, something game-changing and quite unlike anything that was happening 50 years ago, 20 years ago or even 10 years ago. That ‘something’ is the rate of change of complexity of vehicle systems. It is being driven by a number of factors including customer demand for improved features, legislation, driving safety, connectivity, sustainability and, significantly, the move towards autonomous vehicles.

The time is rapidly approaching when it will become virtually impossible to satisfactorily check software-based systems using traditional manual checking and testing procedures. Anticipating this step change, PICASSOS (Proving Integrity of Complex Automotive Systems of Systems) was a three-year research project led by Ricardo and designed to address the problem using Formal Methods. It officially began in 2013 and an end-of-project event was held in February 2017 to share details of the output from the programme.

Software robustness and integrity
Formal Methods are mathematically-based techniques used in computer science which can exhaustively machine-check the robustness and integrity of software systems design; they can do this at a much higher rate and more comprehensively than traditional techniques allow. However, the application of Formal Methods is not so well understood, and that is a mystery the PICASSOS project set out to unravel.

PICASSOS demonstrates how Formal Methods can be applied in the development of safety-critical automotive systems in the context of the ISO 26262 automotive functional safety standard. Ricardo was partnered in the project by Jaguar Land Rover, Johnson Matthey Battery Systems, YorkMetrics, D-RisQ and the universities of Oxford, Coventry and Warwick. The project was part funded by the UK’s Advanced Manufacturing Supply Chain Initiative (AMSCI).

Electronic systems being deployed in the humble passenger car today have a level of sophistication that would only have existed in aerospace applications just a few years ago. Safety and driver assistance systems have come a long way from ABS and cruise control. Faster processing, maturing sensor technologies and economies of scale have enabled features to evolve almost out of all recognition in a very short time.

The advent of Advanced Driver Assistance Systems (ADAS) into the automotive vocabulary has unleashed a torrent of new advanced safety and driver convenience features. The fusion of radar, ultrasonic and camera sensing
technology has enabled a step change in sophistication of those features, especially when combined with a degree of artificial intelligence. Starting from the early days of adaptive cruise control, ADAS inevitably set the industry on a path towards autonomous cars. On that score, SAE Level Three will soon be a reality and the industry is pushing to achieve higher levels of autonomy with the goal being to deliver Level 5, full autonomy, in the coming decades.

Along with passive safety, active safety and ADAS, the electrification of the powertrain has brought about huge leaps in technical complexity, as has secure connectivity, both in relation to delivering improved customer features and as an enabler for autonomy. Systems complexity is thus increasing both due to the increasing inclusion of new functionality, as well as to the increased electronic control over the vehicle’s existing functions.

The challenge of escalating complexity

It would be easy to take this massive escalation in the technical sophistication of vehicle systems as a given, but it presents a very real challenge in terms of the cost and resource needed to develop some of the most complex systems ever contemplated by the automotive industry. As system complexity grows, so does the cost and scale of resources needed to ensure each system’s integrity and robustness. “The supposition within the industry is that technology is on a glide path that will make it increasingly difficult to assess system dependability effectively in production time-frames,” says John Botham, technical specialist at Ricardo’s Cambridge Technical Centre and project leader on PICASSOS.

So what are the traditional manual checking and testing procedures that are rapidly becoming unwieldy in this fast-moving industry? A classic example is Fault Tree Analysis, a well-understood technique that involves a careful step-by-step causal analysis starting with an unwanted event and progressively determining what combination of circumstances led to that event. Essentially, Fault Tree Analysis is a manual technique performed by the human brain and is not a machine-based process. It can deal with combinations but it is weak on sequences and, as a manual process, it relies on the skills of the individual analyst. This is where Formal Methods come in.

“The discipline of Formal Methods has been around since the 1950s and there have been many attempts to make them usable,” explains Botham. “These efforts have been hampered in the past by a lack of computing power. Now, even our laptops are immensely powerful but it’s only in the last few years that commercially available tools have come onto the market allowing us to exploit these techniques to the full.”

Formal Methods toolkits

Formal Methods take many different forms, but all are based on mathematical reasoning. Toolkits have been developed under the PICASSOS project which focus on one of these, called model checking. “A toolkit is a set of approaches which can be assembled in different ways and tailored to a particular problem,” Botham continues. “So the way we’ve assembled them for this project was to think about safety and to think about the sort of vehicle systems we develop at the moment and the way in which we develop them. We have a number of generic techniques for doing this, which slot together and can be adapted within the existing development processes. The approach can be tailored to suit an individual organisation’s specific needs and what it requires the toolkit to do.”

Model checking involves creating a model of the system using familiar engineering software; then, as the name suggests, the process checks the model to find out whether it does or does not satisfy an assertion under all circumstances. The beauty of this approach is that the user does not need to understand the mathematical processes going on ‘under the hood’ – the tool itself is designed to accept Simulink and Stateflow models.

“The system models contain representations of components, the states they can be in, and what their functions are – plus any added faults. Our toolkit then converts that engineering model into a mathematical form that the computation engine in the model checker uses,” explains Botham. Once it has been given the mathematical model of the system and a number of assertions or propositions the engineer wants to check, the tool crunches the numbers and delivers the results. How it does that is transparent to the user.

The alternative would be to write code to perform a lot of individual tests by hand – something that, given the complexity of the systems in question, is becoming increasingly impossible. The amount of time needed to achieve the necessary verification is increasing and there is a limit to the amount of resource available, both in terms of cost and practicality. Another dimension is that the level of risk is increasing due to autonomous operation and the way in which more and more systems are interconnecting.

“Testing is always selective,” Botham says. “You can always wonder whether you have a good enough set of test cases.” One of the most appealing aspects of using the automated Formal Methods approach is that it takes the worry away. The tool rigorously performs exhaustive checks into virtually every possible permutation of circumstances in a way that simply would not be feasible using manual techniques. “You don’t need a very complex model before the human brain is simply incapable of seeing all the sneak paths through the system,” Botham adds.

However fast and relentlessly thorough the machine-based model checking procedures may be, the tools are selective. “It’s not all about brute force,” explains

“The supposition within the industry is that technology is on a glide path that will make it increasingly difficult to assess system dependability effectively in production time-frames” John Botham, PICASSOS project leader
Botham: “the tools are smart in that they don’t check every combination but prune the search back where possible.”

System checking using machine-based Formal Methods thus promises to be highly effective. It should enable engineers to find any defects earlier in the process, reducing cost and impact on overall timeframes. Despite the fact that faster techniques for checking systems are necessary, Botham is quick to point out that even with the use of Formal Methods, there are limitations. “What we don’t want to be seen to be doing is throwing these technologies at a problem and claiming that nothing can ever go wrong,” he emphasises. “What we do have is a toolkit which can be potentially applied at attack points, different classes of problem and indeed, potentially, different aspects of vehicle behaviours.” Part of applying these techniques is to use a model that captures aspects of a problem the user is trying to analyse. There has got to be an abstraction in the sense that the process is only telling users things they are looking for an answer to in the first place.

Achieving confidence and reliability

So will the introduction of these advanced system checking procedures directly benefit and users in terms of vehicle functionality? Or are they just a way of keeping manufacturers out of trouble, by enabling them to keep control of the fast accelerating complexity of vehicle systems that are being demanded by the market?

The answer is two-fold. Yes, the new techniques will allow manufacturers to keep pace with the complexity of systems and achieve the confidence in them that the world demands. But they will also help deliver, within standard development timescales, the reliability of functions and dependability consumers want and, most importantly, at a cost the consumer can afford. Beyond that, there’s the question of on-going change. The prospect of struggling on with manual methods such as Fault Tree Analysis to achieve the initial goal is one thing, but what happens when a model change intervenes? The increase in complexity means the burden of revising those systems will multiply and the introduction of the methods developed within PICASSOS will undoubtedly help to relieve that burden.

However, what the new techniques should not be viewed as is as an enabler for autonomous vehicle architecture. The scope of the guiding standard, ISO 26262, is expected to be expanded but the industry already recognises that it will not be sufficient to fully address the risks or identify all the sources of risk associated with autonomous vehicles. The exact definition of which tools to use has yet to be decided, but it is likely that will remain flexible to suit client needs. “Unless a client has dictated a tool set, it would be our choice as to what we use. We are in the process of weighing up the cost and limitations of tools available to them that the world demands. But they will also help deliver, within standard development timescales, the reliability of functions and dependability consumers want and, most importantly, at a cost the consumer can afford.”

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Ricardo assists Toyota on fuel cell truck project

The successful application of a heavy-duty hydrogen fuel cell system to a Class 8 truck – in the demanding environment of the ports of Los Angeles and Long Beach – is the goal of Toyota’s ‘Project Portal’. Ricardo has provided technical assistance in areas of design, vehicle build, testing and development, and is currently supporting vehicle trials.

Project Portal is the latest step in Toyota’s effort to broaden the application of zero-emission fuel cell technology. It is a fully functional heavy-duty Class 8 truck with adequate power and torque capacity to conduct port drayage operations, while emitting nothing but water vapour. Heavy-duty vehicles make up a significant percentage of the annual emissions output at the ports on San Pedro Bay, so the Portal feasibility study offers a potential path to further reduce these emissions.

The truck generates more than 670 horsepower and 1800 Nm of torque from two Mirai fuel cell stacks and a 12 kWh battery, a relatively small power pack for Class 8 load operations. The concept’s gross combined weight capacity is 36,000 kg, and its estimated driving range is more than 320 km per fill under normal drayage operation.

Ricardo’s input has covered a wide range of engineering functions, notably systems integration and packaging, including the fuel cells, power electronics, hydrogen tanks, cooling systems, batteries, electric motors and transmission. Many of the ancillary systems that are traditionally driven by the engine were also electrified, including the air compressor, power steering and HVAC system, the controls of which required integration into the vehicle’s J1939 CAN BUS.

“Heavy-duty trucks are generally not amenable to the types of electrification used for passenger cars and other light duty vehicles, due to the size and cost of the required battery systems”, commented Chris Brockbank, VP of Vehicle Engineering at Ricardo. “For this reason, Project Portal provides an exciting opportunity to evaluate a further, practical option for a heavy truck zero emission vehicle application. We look forward to working with Toyota in the completion of the in-port trials, and to seeing the results of the project which, I believe, may well inform the future vision of heavy duty transportation.”

Automated train technology in China to be certified by Ricardo

Ricardo is to provide Beijing Traffic Control Technology Company with product certification services for the upgrade of its Automatic Train Supervision (ATS) technology, ahead of its application on the Guiyang Metro.

The new ATS system will run on Line One of the new urban transit system in Guiyang, south-west China, when construction is finished later this year. Its assessment – to be completed this summer by experts from Ricardo Certification – will be performed against the relevant CENELEC standards. The Ricardo team will undertake rigorous documentation checks, act as on-site witness on the validation test programme, and perform a range of on-site audits.

The contract continues Ricardo Certification’s important contribution to the rapid development of China’s urban transit networks. In the period between 2009 and 2015, almost 90 transit lines were opened across 20 different cities, with Guiyang one of 11 cities that will open their inaugural transit lines over the next four years.
Ricardo has joined the 5*StarS Consortium, which will address the critical importance of cyber security in the era of connected and autonomous road vehicles. The initiative, which will receive grant funding from the UK’s innovation agency, Innovate UK, partners Ricardo with hRiBA, MiRA, Roke, Thatcham Research and Axillium Research, to launch the ‘Automotive Cyber Security through Assurance’ project.

The consortium will research and develop an innovative assurance methodology to ensure that connected autonomous vehicles, components and systems are designed and tested to the relevant cyber security standards throughout their whole life-cycle. The ultimate aim of the consortium is to develop a 5-star type consumer rating framework, analogous to existing EuronCAP type ratings for vehicle safety.

“This project will help to clarify the risks associated with increasingly connected and autonomous vehicles and cloud connections,” noted Ricardo cyber security specialist Andrew Ashby. “It will also help to build consumer confidence and thereby boost the commercial opportunities for this exciting new technology in the UK, and we at Ricardo are delighted to be playing a part.”

Roadside real-world emissions monitoring launched

A significant step forward in the facilitation of pollution control came with the launch of Ricardo’s new roadside monitoring system, which instantaneously records the driving emissions of every passing vehicle – and identifies each vehicle type. The new system – developed by Ricardo with technology partner OPUS Inspection, and demonstrated in May at the Air Quality & Emissions Show (AQE), in Telford, UK – uses absorption spectroscopy to monitor and record emissions of nitric oxide, nitrogen dioxide, particulate matter, hydrocarbons, carbon monoxide and ammonia. A link to automatic number plate recognition (ANPR) cameras enables vehicle identification, the matching of emissions data to characteristics such as engine type and age, and the pinpointing of non-compliant vehicle classes.

The non-intrusive system can measure emissions at a chosen location of interest from thousands of vehicles in a short space of time: Ricardo has gathered data from over 20,000 during preliminary work. Early results include a direct comparison between Euro 5 and Euro 6 engines under real-world driving conditions, and the impact that cold-starts have on petrol and diesel engine emissions in urban environments. The data promises important insights for cities and local authority planners on how to develop Clean Air Zones and other air pollution mitigation measures, and could assist with enforcement too.

“Ricardo has a strong history in emissions measurement and is one of the only organizations equipped to offer the three main methods for vehicle emissions monitoring – in the laboratory, with a PEMS kit, and through the use of remote sensing,” said Sean Christiansen, Ricardo Energy & Environment air quality practice director. “This new real-world monitoring system adds to the extensive air quality capabilities that Ricardo offers: these range from support and advice on pollution control policies, to pollution modelling and measurements, inventory design and compilation, and the development of low emission strategies.”

Ricardo contributes to automotive cyber security

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Full steam ahead for Tornado

In April this year a steam locomotive ran at 100 mph (162 km/h) on the UK rail network for the first time in some 50 years – and Ricardo’s accreditation experts played an important part in helping it to reach this milestone.

When steam locomotives began to be replaced by electric and diesel-powered units during the 1950s, many redundant models ended up running on preserved lines, or as museum pieces. Not so, unfortunately, the Peppercorn Class A1 – all 49 of which were scrapped.

In 1990 a group of enthusiasts, the A1 Steam Locomotive Trust, embarked on an ambitious project: to design and build a Peppercorn Class A1 fit for the modern rail network. In 2008, after almost two decades of painstaking work, the locomotive Tornado finally entered service.

This April, in a test run overseen by Ricardo Rail’s experts on a stretch of track between Doncaster and Newcastle, the Tornado became the first steam engine in almost half a century to reach 100 mph on the UK main line. By proving it can operate safely at higher speeds, the locomotive, which is operated by DB Cargo, will find it easier to secure access to the network – which is always at a premium.

As required by the certification standard applicable to steam locomotives in the UK (GM/RT2003), Tornado’s regular audit was carried out in March by Eddie Draper, a principal consultant at Ricardo, who has been engaged with the project for some time.

“Although Tornado was designed as a 90 mph vehicle, since 2008 it has operated with a speed limit of 75 mph,” he explains. The higher speed test run thus meant further inspection work for Draper, including an examination of the new temperature transmitter for the middle big end bearing, the design and installation of which he had had previously approved. The strong media interest brought challenges, too: “By the time I had arrived, a television crew was already in place fastening cameras all over the loco, so I gave these the once over for gauging and security,” he recalls.

During part of the run Draper rode on the footplate to evaluate performance, including some very particular technical challenges. “Steam locomotives have large reciprocating masses connected directly to the axles, and attempts to balance these with rotating balance masses in order to improve the ride can lead to large out-of-balance vertical forces on the track”, he notes. The test run, however, went without a hitch, meaning that Tornado remains on track to complete the necessary certification processes within the next 12 months.

Meanwhile, both Draper and Ricardo are looking further ahead. “There are only two accredited signatories for heritage vehicles in the UK, and both of us work at Ricardo,” Draper says. “So succession is something we are thinking about, and we are currently training a young chartered engineer to take over. It’s important to us – and to the industry as a whole – that we can continue to support the safe operation of our heritage fleets.”

Ricardo scoops Forbes award

For the second year running, Ricardo Strategic Consulting has been commended by Forbes as being among the leading management consultants in the United States. Compiled in association with online statistics provider Statista, Forbes’ America’s Best Management Consulting Firms 2017 is a list identifying the management consultancies that are providing business sectors with the best guidance on their practice. There are 50,000-plus such firms currently active.

“Across multiple industries and market sectors, Ricardo has a strong commitment to assisting customers in meeting some of the most pressing challenges of today in terms of regulatory compliance and increasing energy efficiency, operational effectiveness and profit, while also meeting their wider environmental and corporate social responsibility objectives,” said Markus Doerr, global managing director of Ricardo Strategic Consulting. “We’re honoured to be recognized again by Forbes for our ability to support our clients in the American market.”
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