GATEway

Safety and Insurance

Ensuring safety for autonomous vehicle trials

Question:

What was the GATEway project and what did it aim to achieve?

Answer:

The GATEway (Greenwich Automated Transport Environment) project was an £8 million research and development project designed to understand and overcome the technical, legal and societal challenges of implementing connected and automated vehicles in an urban environment. The project was funded by industry and Innovate UK and was delivered by a consortium led by TRL.

The GATEway automated vehicle trials were conducted in the UK Smart Mobility Living Lab™ (SMLL) which encompasses the entirety of the Royal Borough of Greenwich. The UK SMLL™ has been created by TRL, with the support of the Royal Borough of Greenwich, and with approval from the Centre for Connected and Autonomous Vehicles (CCAV), the Department for Transport (DfT) and Innovate UK.

As part of the overall GATEway program, three automated vehicle trials were carried out in urban locations within the Royal Borough of Greenwich: A passenger vehicle service, a vehicle parking service and a local delivery service.

The project has helped both industry and policymakers understand the implications of automated vehicles delivered in a safe, validated test environment in the UK; as well as providing the public with direct experience of automated vehicles and collecting novel sociological research to understand the potential for job creation, opportunities and investment in this rapidly emerging area of technology.

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Question:

How do you define an autonomous vehicle?

Answer:

SAE International (a United States-based organisation originally established as the Society of Automotive Engineers (SAE)) developed a six-level system for defining a vehicle's level of autonomy, as shown in the table below adapted from SAE International's J3016 standard "Taxonomy and definitions for terms related to on-road motor vehicle automated driving systems".

Those levels range from assisted driving – technologies that support steering, acceleration or braking but where the driver must remain actively engaged in the driving task and monitoring the road situation ahead at all times – through to fully autonomous vehicles – able to undertake a full journey door to door in automated mode without driver input. The SAE levels were designed to provide clarity on the requirements for driver input and have been adopted by the industry.

The current UK Automated and Electric Vehicles Bill, which is currently progressing through Parliament, defines an automated vehicle as: *"a vehicle capable of operating in clearly defined automated mode(s) which can safely drive the vehicle in specified design domains without the need to be controlled or monitored by an individual".*

To meet this definition, the vehicle must meet minimum criteria for its automated systems; consequently a system that requires the driver to control or monitor the vehicle in any way cannot be classified as automated.

SAE Level	Name	Execution of Steering and Acceleration / Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Tasks	System Capability (Driving Modes)
Human driver monitors the driving environment					
0	No Automation	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	Human driver + system	Human driver	Human driver	Some driving modes
2	Partial Automation	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment					
3	Conditional Automation	System	System	Human driver	Some driving modes
4	High Automation	System	System	System	Some driving modes
5	Full Automation	System	System	System	All driving modes

Question:

How did you ensure safety when there was limited legislative guidance?

Answer:

Ensuring safety throughout the lifecycle of the three trials was a priority for TRL, consortium partners and stakeholders. In the absence of relevant safety standards and learning from previous autonomous vehicle trials, we developed a safety case framework using the requirements set out in The Pathway to Driverless Cars: A Code of Practice for Testing (DfT, 2015) as our baseline.

A safety case was developed for all three trials with the following requirements:

- To demonstrate that the trial was safe and that risks to all affected parties had been identified, managed and reduced to a tolerable level.
- To demonstrate compliance with applicable existing legislation, standards and guidance.
- To provide the required evidence and reassurance to the Royal Borough of Greenwich, relevant land owners and Royal Sun Alliance (RSA) for permissions and insurance respectively.

A comprehensive risk assessment was at the core of the safety case with supporting evidence for each of the risk decisions made; further information regarding the risk assessment is described later within this report.

The safety case was a live, iterative document throughout the trials to ensure lessons learned were fed back into the risk assessment and the associated mitigation measures.

The GATEway project gave us the opportunity to create a robust approach for manging safety and risk during autonomous vehicle testing and operation to satisfy the requirements of all stakeholders. It also gave TRL the opportunity to develop an industry-leading safety standard that can be used as a base for the future deployment of trials and vehicle testing.

Question:

What were the key risks and how were they evaluated and overcome?

Answer:

A workshop was held with relevant technical experts from key industries, organisations and members of the project consortium to identify perceived hazardous scenarios. Following this an evidence review was undertaken using the available literature and guidance to verify identified hazards and determine others that had not already been captured.

The hazardous scenarios were developed and supplemented throughout the GATEway project to reflect: the trial design, vehicle specification, autonomous control system (ACS) capabilities, and lessons learned from ACS monitoring, incidents and near misses.

Risks were evaluated using a risk matrix developed by TRL for the autonomous vehicle trials with the following outcomes:

Residual Risk	Action Required
Green	An acceptable level of risk. Continue adhering to current safety requirements.
Amber	An acceptable level of risk. Continue adhering to current safety requirements.
Red	Tolerable level of risk. Do not continue the activity until controls have been reviewed and risk is as low as reasonably practicable.
Black	Unacceptable level of risk. The trial must not proceed or continue until the risk has been reduced.

RISKS				MITIGATIONS			
Collision with Ped/Cyclist/Veh	Collision with object/infrastructure	ACS subject to cyber attack	Stewards subject to abuse	ACS and vehicle design	Cybersecurity	Route assessment	Safety Stewards and Marshals
Injury claims	Vehicle not operating as expected	Injury on board vehicle	Theft / vandalism	Safe working practices	Emergency response plan	Reporting and monitoring	Safety testing

Question:

How did you ensure the trials were safe?

Answer:

Risks were assessed and evaluated in the safety case and mitigations identified. Mitigations (outlined on the previous page) included safety testing of the ACS, testing the safe operating boundaries of the ACS (such as smallest object detection both at a set distance and close to the vehicle), a Safety Steward on board the vehicle at all times, staff selection and training, and safe working practices.

The vehicles and autonomous control systems used for trials were subjected to robust safety and acceptance testing in order to ensure that they were safe and the vehicle capabilities were fully understood and documented. This involved testing the basic vehicle features (e.g. lights, indicators, horn), sensors (to test object detection), autonomous functionality (including the autonomy engagement and disengagement process), safe operating boundaries and stopping distances.

Trial safety was further enhanced by having selected and trained Safety Stewards who remained inside the vehicles at all times monitoring the vehicle's automated driving, the route and the ACS functionality. Stewards were required to intervene if the vehicle behaved unexpectedly or the ACS displayed any fault warnings. Typical interventions comprised stopping the vehicle, engaging 'creep mode', which reduced the speed of the vehicle to walking pace or manually intervening if required.

In addition to Safety Stewards, Marshals were required at each of the four route stops to manage passengers and members of the public, answer any queries, ensure they completed the required surveys and provide assistance when passengers were embarking and disembarking vehicles. Additionally, one roving Marshal was used to assist Stewards when manual vehicle interventions were required or to assist Marshals at the route stops. Further information regarding trial staff roles and responsibilities is shown in the Trial 1 (passenger vehicle service) report.

Safe working practices were also developed and communicated to personnel involved in trial activities including: trial safety overview (documenting trial-specific risks, mitigations and rules, and incident and near miss reporting), Steward impairment, lone working, vehicle checks, security, maintenance and cleaning. Furthermore, Stewards and Marshals were required to meet specific selection criteria and undertake competency training.

Question:

What safety features did the vehicles have?

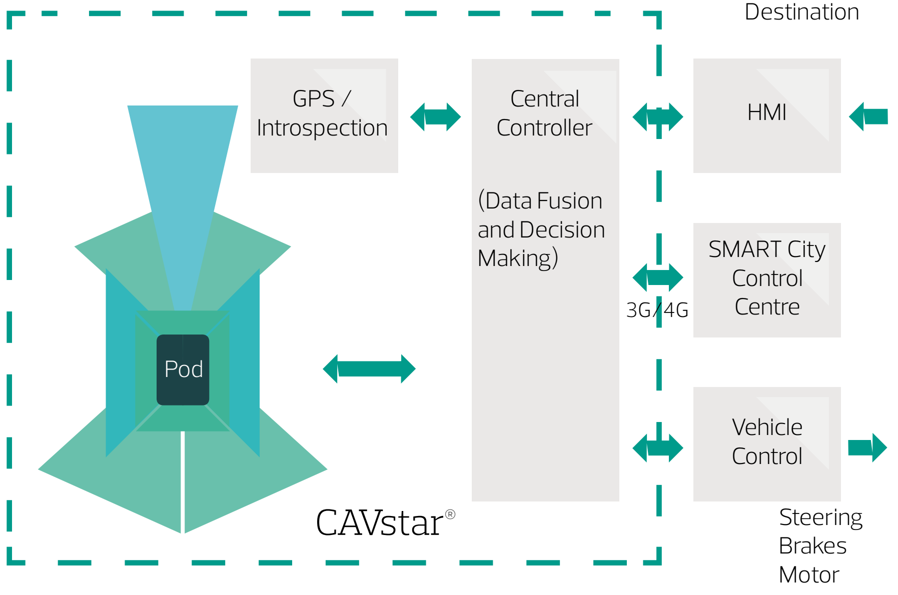
Answer:

The vehicles were equipped with multiple safety features, including via the autonomous control system, manual controls available to Stewards, interior safety features and exterior safety features.

ACS Safety Features

The ACS was pre-programmed to reduce the vehicle's speed at hazardous locations along the route, such as intersections or blind corners. Vehicle speed could also be manually reduced by the Steward on any section of the route using the 'creep mode' switch on the button array inside the vehicle. The creep mode switch reduced vehicle speed to 1m/s (approximately 2mph) and was designed to provide Stewards with greater thinking and reaction time in response to hazards or high-risk situations and to reduce the consequence severity in the event of a collision.

Pod System



Question:

What safety features did the vehicles have? *Continued*

Answer:

Vehicle Platform Safety Features

The vehicle's button array included a horn (which was used to warn other route users of the vehicle at hazardous locations and in other circumstances where deemed necessary by the Steward) and an emergency stop button, to be engaged if they felt it was necessary to do so.

Other interior safety and crashworthiness features were incorporated into the vehicle compartment design; there were no protruding or sharp contact surfaces, which reduced the risk of injury in the event of passenger impact with the vehicle interior, the floor was constructed from non-slip material, seating was made from fire-proof material and four low-level grab handles were situated adjacent to the seats. All vehicles included a first aid kit, break glass hammer and fire blanket to be used in an emergency. The passenger compartment also included a smoke detection system which, upon activation, sent an alarm to the Steward and triggered forced air ventilation.

Exterior vehicle safety features were incorporated into the vehicle design to minimise pedestrian injury. These included: a smooth vehicle shape; and low bumpers made of energy-absorbing, deformable elements. The bumpers (both front and rear) comprised sensors at 250mm above ground level that were sufficiently sensitive to be triggered by any small objects which resulted in the vehicle's Main Vehicle Computer applying the brakes.

Emergency door release pulls were located on each side of the vehicles, with disable autonomy buttons on the nearside of each vehicle. Emergency exit from inside the vehicle was possible by smashing the glass using the break glass hammer. Vehicle conspicuity was increased by utilising conspicuous wrapping, fitting an audible warning system via a noise generator, and by providing visual warning via an amber roof-mounted flashing LED light. Both the noise generator and LED light were activated whenever the vehicle was in motion, both during manual or autonomous mode. All vehicles were fitted with vehicle headlights and taillights, including brake lights, hazard lights and indicators; vehicles were not fitted with reversing lights as they were not capable of reversing in autonomous mode.

Question:

How did you know you could trust the ACS and it was reliable?

Answer:

All of the vehicles' autonomous controls systems, which were part of Fusion Processing's CAVstar® system, were subjected to robust safety and acceptance testing in order to ensure that they were safe and reliable. This involved testing all of the sensors that were part of the sensor system (shown in the diagram on p.12): Radar, LiDAR, CycleEye®, ultrasonic sensors and bumper strip sensors to verify their short, medium and long-range object detection and that the system, and therefore the vehicle, would respond appropriately by slowing or stopping. The tests also included examining each vehicle's safe operating boundaries against both static and dynamic objects of varying size at varying distances. This was supplemented by pedestrian and cyclist detection tests both from the front and rear of the vehicle together with the real-world stopping distances of each vehicle at different speeds from 1 - 2.5m/s (approximately 2-5mph).

Similarly, each vehicle's autonomous functionality was tested by checking the system's route navigation, whether the vehicle stopped automatically at each of the designated stops along the route and the systems robustness in varying weather conditions. Further tests were undertaken to examine the engage/disengage autonomy process, the operation of the 'creep mode' switch, as well as the safeguards and preconditions that automatically cancelled or prevented autonomy being engaged in certain circumstances, for example if a sensor was accidentally disconnected.

If one or more vehicles did not pass the testing, the reason(s) for failure were documented appropriately to enable the issue(s) to be rectified and the system to be re-tested for sign-off prior to going into service. Once signed-off, all vehicles' reliability was assessed over the course of several autonomous journeys along the route which also enabled the functionality of the Fleet Management System to be tested, particularly regarding how vehicles behaved when approaching one another and what commands and information were provided to Stewards.

Question:

How did you mitigate cyber security risks?

Answer:

Cyber security risks include: malicious/cyber-attack, accidental damage during system maintenance, inability to recover data due to error and insecure or untested hardware or software. The risks could be caused by any of the following: networking of computers and systems, vehicles linking to other vehicles or infrastructure or deliberate/accidental planting of viruses.

The risks were addressed by utilising secure internet and communications platforms, encrypting the vehicle software and hardware, and ensuring that the ACS 'failed-safe' by stopping the vehicle if unsolicited access was detected. In addition, the ACS was subjected to penetration testing and was physically separate from other safety-critical elements of the ACS to reduce the severity of the consequences in the event of successful unsolicited access.

The project has shown that appropriate technical and organisational measures need to be in place to protect the integrity of the vehicles and their systems which ultimately starts with the manufacturer. High levels of technical safety, including suitable cryptography, layering, separation and identity authentication, should be continuously refined for the software, firmware and hardware architectures of the vehicles as well as remote access to the vehicle via telecommunications networks.

Guidelines for insuring a vehicle's cyber security are currently being developed through the World Forum for Harmonization of Vehicle Regulations at the United Nations Economic Commission for Europe. The regulations include the requirements for implementation of verifiable security measures based on existing security standards, measures to manage integrity protection and use of cryptographic keys, protecting internal communications between controllers and strong, secure authentication and communications for remote access for online services.

RSA and other Insurers support these guidelines and will need to consider their future approach to cyber security and motor vehicles including suitable limits and conditions. At present, an owners damage or third party loss caused by a cyber security event would be considered within the terms of a motor policy.

Question:

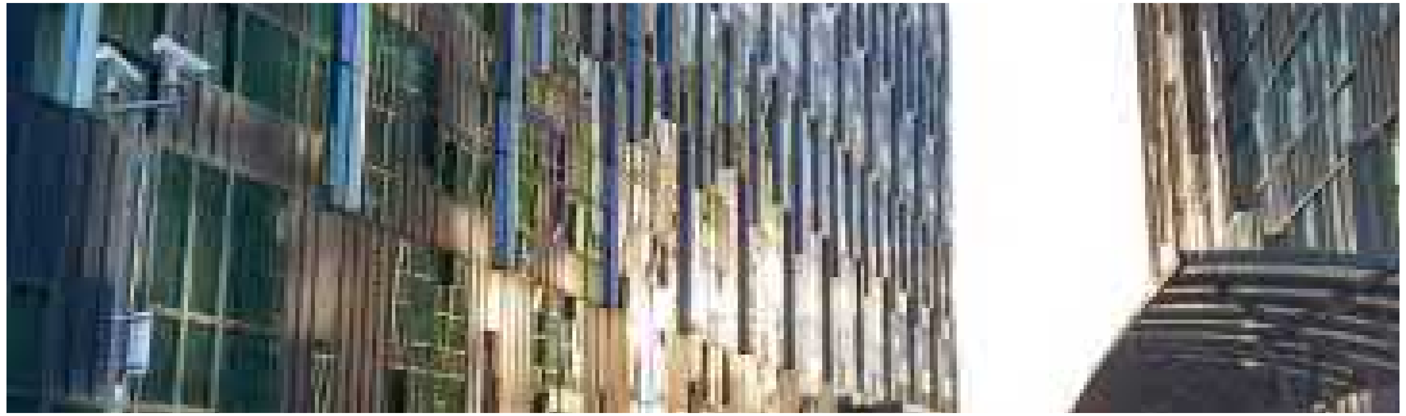
How do you ensure the physical security of an autonomous vehicle?

Answer:

Physical security of an autonomous vehicle is similar to that of a conventional vehicle. Insurers would expect keys (or proxies for keys such as digital media devices) to be removed when leaving the vehicle unattended and kept in a secure place separate from the vehicle. Vehicles should also be secured against theft or malicious damage when left unattended or overnight.

There is a general duty on an insurance policyholder to take 'reasonable precautions' to prevent injury, loss or damage and the requirements for the owner or operator of an autonomous vehicle would be the same.

For the trials vehicle keys were stored in a lockable safe whilst all vehicles were secured in a safe storage cage. The vehicle keys and vehicles were stored at separate locations to reduce the likelihood of potential theft or damage but they were close enough to ensure that both were easily accessible by the trials team.



Question:

How did you know where to (and where not to) run the trials?

Answer:

Initially, consideration was given to the broader location of the routes, not only being within central London, but within the Royal Borough of Greenwich. TRL's UK Smart Mobility Living Lab™ encompasses the entirety of the Royal Borough of Greenwich and is a real-life, open innovation testing environment where Connected and Autonomous Vehicle (CAV) systems, services and processes can be safely developed, evaluated and integrated with the local environment.

The route selection process involved undertaking detailed site assessments to explore feasibility for the vehicle, based on: the project aims and use case, requirements to avoid or minimise interaction with other vehicles, the available space, and the potential risks to other route users. All affected land owners and stakeholders were consulted and shown route plans which led to the final route being chosen in principal, subject to a route safety assessment.

The route safety assessments were carried out to ensure that the route was appropriate for the vehicles' known capabilities and limitations and to identify any potentially hazardous scenarios, locations or route features. The assessment also focussed on the forward-facing visibility for the Steward, type and condition of the route surface, height and width clearance for the vehicle, and presence of any obstructions.

Question:

Were there any incidents during the trials?

Answer:

There were four recorded incidents during the trials, however there were no serious incidents and no reportable claims for insurance purposes. The four incidents comprised of two minor incidents and two near misses, and were caused by the following:

- A pedestrian purposefully testing the autonomous capabilities of the vehicle (particularly object detection response).
- Two pedestrians being unaware of the vehicle's operating capabilities and behaviour when it was travelling in automated mode.
- A Safety Steward being distracted by passengers whilst monitoring the vehicle as part of the steward role.
- The vehicle's ACS misjudging a bend on the route.

In all of the incidents described above there was no injury to any affected parties or damage to infrastructure. Two of the incidents resulted in trial vehicles sustaining minor damage to paintwork only.

Lessons were learned from these incidents and action was taken to prevent recurrence.

Question:

What would have happened in the event of an emergency?

Answer:

An emergency response plan was developed to ensure that a clear and effective response was implemented to manage any incident or emergency and to ensure the safety of all affected parties. The plan was developed in consultation with local emergency services, stakeholders and members of the consortium, in order to confirm that it was suitable for a range of potential types of emergency and that it aligned with local emergency responders' existing response procedures. The plan also incorporated evacuation and welfare plans to assist with scene management and to provide support to any affected parties. All members of the trials team were trained to implement the plan if required.

An incident communications plan was developed in parallel with the emergency response plan to facilitate effective communications during an incident and to ensure the safety of the project team, members of the public and the successful operation of the GATEway project. This involved applying measures to enable an integrated and coordinated approach between the project and communications teams and project partners, to ensure that clear and consistent messaging was conveyed to the right people at the right time and to provide reassurance to GATEway stakeholders. A steering committee was created to bring together relevant parties and to tackle any reputational threat that could have arisen as a result of an incident.

Question:

What data was monitored and how?

Answer:

For the passenger vehicle service trial, Stewards were responsible for monitoring vehicle and ACS data via a dashboard within each vehicle, which provided the monitoring and control interface. The lower half of the dashboard contained a mounted iPad tablet in landscape orientation which was used to monitor critical vehicle status messages (such as battery charge and temperature) and receive and review feedback on the state of the ACS and its hazard detection. Appropriate action could be taken by the Steward to address any issues and fault messages. All data was recorded in line with the DfT Code of Practice.

Monitoring of an additional dataset, the Fleet Management System (FMS), was also undertaken to analyse vehicle parameters. The FMS was provided by Fusion Processing, the ACS supplier, and was designed to provide the following functions:

- Vehicle fleet management - to ensure that all vehicles maintained an appropriate distance and schedule along the single-lane route, and could be assigned destinations as required;
- Vehicle overtaking – the system could command individual vehicles to pause whilst another passed it to ensure two-way traffic in the single vehicle lane; and
- Vehicle monitoring – status of critical vehicle functions could be monitored remotely, including location, speed, whether the vehicle was travelling in autonomous mode, temperatures (battery, cabin, motor) and battery state of charge.

The FMS operated in the background and was monitored by a member of the Fusion Processing team. Data was transmitted between the FMS and each vehicle using a secure cellular network.

For the vehicle parking service and local delivery trials, data was recorded within the vehicle in line with the DfT Code of Practice.

GATEway
Autonomous Vehicles
Ensuring Safety
Key Risks
Safe Trials
Vehicle Safety Features
Reliable ACS
Cyber Security
Physical Security
Running Trials
Trial Incidents
In Emergencies
Monitored Data
Permissions to Trial
Safety Outputs
Traditional Insurance
Challenges for Industry

Question:

What permissions needed to be obtained to run the trials?

Answer:

In order to run novel trials like these on the Greenwich Peninsula Thames Path, it was essential to receive relevant approvals and engage with all land owners, highway authorities, emergency services and local community groups for the proposed route. The land that was used is owned by the Royal Borough of Greenwich. TRL obtained permission from the Royal Borough, the InterContinental Hotel – The O2 and the Royal Arsenal to carry out all three trials. In conjunction with the Royal Borough, TRL liaised with local residents and businesses to ensure that the nature of the trials and the risk mitigations were explained and approved. Specific infrastructure requirements, such as trial-related signing, were agreed with the relevant authorities.

The legal status of the route sections was established with the relevant parties. The cycleway on the Peninsula used in the passenger vehicle service trial is not a designated cycle route but is a privately-owned permissive route which allowed it to be assigned as a vehicle lane for the trial. This was achieved by implementing an approved signing and route marking scheme, applying vehicle pictogram markings and a lane marking to separate the vehicle lane and the pedestrian/cyclist lane.

The emergency services were also engaged in order to facilitate co-operation in the event of an investigation and to ensure that they were aware of the Emergency Response Plan and familiar with the features of the automated vehicle should an incident occur.

Question:

What have been the safety outputs from the trials?

Answer:

Safety Case Framework

Iteratively developed throughout the trials and provides a robust, validated and repeatable approach for managing the risks associated with autonomous vehicle testing. This framework is now being applied to additional CAV projects within the UK and internationally.

Autonomous Vehicle Testing Risk Assessment

Considers the entire lifecycle of autonomous vehicle trials, evaluates risks to all affected parties and determines tolerability of risk using a risk matrix designed specifically for autonomous vehicle testing.

Route Safety Assessment Methodology and Criteria

The route safety assessment methodology enables routes to be classified for CAV testing based on their perceived difficulty and to assess their suitability and identify hazards using a defined process.

Code of Practice Compliance Matrix

Provides a means of documenting the level of compliance with the CoP prior to autonomous vehicle testing.

Safety and Acceptance Testing Protocols

Protocols have been developed and can be used or tailored for future autonomous vehicle testing. The protocols provide relevant persons with recommendations regarding what 'safe' looks like.

Safety Requirements and Safe Working Practices

Developed throughout the project based on existing legislation, guidance and the output from the risk assessment. Safe working practices were developed for personnel involved in trial activities.

Emergency Response and Crisis Comms Plans

Developed to ensure appropriate responses to minimise consequence severity. The process and framework could be applied to future CAV trials.

Autonomous Vehicle Trials Hazardous Scenarios

A library was created to understand required autonomous vehicle capabilities to safely navigate different route types on the UK road network. This can be used to help steer the safe selection of routes for autonomous vehicle trials.

Question:

How would a traditional insurance policy respond to the challenge of autonomy?

Answer:

Currently, insurers underwrite and price insurance based on the risk presented, likelihood of an event occurring, the likely cost of that event if it does occur and, for a traditional policy, features such as driver details, vehicle make/model, type of use, driver occupation and location of vehicle and security.

Current insurance premiums tend to look at historical data, including the number of events given the features of the driver, vehicle and types of use. For autonomous vehicles this view of pricing is less relevant: new and 'unproven' technology will not have relevant historical data to benchmark against. In addition, the majority of pricing in traditional policies is based on driver characteristics – this is not necessarily the case for an autonomous vehicle.

For an autonomous vehicle, the general policy conditions continue to be valid. Current policies include a condition that the Policyholder should take and cause to be taken all reasonable precautions to prevent injury loss or damage and shall maintain the insured vehicle in a roadworthy condition.

The current Automated and Electric Vehicles Bill reinforces this by including a section on unauthorised software alterations or the failure to update software. Once legislation is in force, an insurance policy may exclude or limit some liabilities.

New regulations will also need to include provision for regulatory testing, such as extending the MOT to include tests on the vehicle hardware and software systems.

Insurance for autonomous vehicles used in trials to date has been underpinned by a comprehensive safety case and implementation of appropriate mitigation measures. The trials have demonstrated that autonomous vehicles do have common characteristics that can be taken into account – such as locations, use, and value – which, when taken with the safety case, enable realistic valuation of risk.

Question:

What are the key challenges for the insurance industry in the future?

Answer:

Policy, Claims and Pricing Considerations

There are a number of key challenges that the insurance industry will need to address:

- Motor insurance is essentially an 'All Risks' cover, so will be able to adapt to new and emerging covers, however the biggest challenge will be around the Underwriting and Pricing of fully and highly autonomous vehicles. A key challenge will be around the movement from using the 'Driver' as one of the key rating factors, to having the performance of the software, hardware, algorithms and manufacturer philosophy as key determinants of incident frequency and severity. Coupled with the fact that the industry relies on historic performance and data as a key mechanism for pricing risks – moving forward much of this data will be redundant and vehicle insurance will be based on new data sources and factors.

Other implications that are likely to arise out of new legislation and emerging technology include:

- The fact that insurers will become responsible for accidents involving vehicles operating in an autonomous mode.
- With the driver effectively being a passenger whilst the vehicle is operating in an autonomous mode, they will be entitled to compensation even if their own (automated) vehicle is 'at fault'.
- The changing dynamics of frequency and severity of claims as automated systems, sensors, and accident detection and avoidance technology in vehicles increases.
- The emergence of new covers – cyber security for example is likely to become an important feature of future Motor policies.
- The movement towards autonomy is likely to happen alongside an increase in electric vehicles, and changing usage and ownership models for vehicles generally.

Question:

What are the key challenges for the insurance industry in the future? *Continued*

Answer:

Data storage and interrogation

The rise in technology in vehicles, and increasing amounts of data they are generating raises interesting challenges for the Insurance Industry and Manufacturers. Readily available access to data (in a timely, consistent format and equally available to the Insurer and Manufacturer) in the event of a loss will ensure more timely and equitable settlements for all parties. Impartial access to technical and occupant information data will allow a fact-based assessment to be carried out which looks at the cause of any incident, loss or damage.

The Association of British Insurers (ABI) in conjunction with Thatcham has designed a check list of key data fields that should be mandatorily recorded and stored for potential analysis in the event of a loss and to help assign liability.

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2018

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