CAVT Ltd – Written evidence (AUV0061)

A crucial issue not captured under the questions posed, and its salience

There is a widespread and partly mistaken view that dramatic decreases in incidents will be achieved by adoption of autonomous vehicles (AVs); this is often used to justify promotion of autonomous vehicle programmes and policies. A figure of 90% or higher is commonly quoted as the potential reduction in crashes, attributed variously to official USA data. Here follows a summary analysis made by CAVT Ltd of the data which has already been presented at conferences but not yet published in full. It is therefore included here in the hope that it can be considered to meets the Guidance for this call for evidence.

In 2015, the Conference Board of Canada published a report by Gill, Kirk and Godsmark entitled Automated Vehicles: The Coming of the Next Disruptive Technology which included the statement:

AVs have many benefits: the most significant is safety. By removing the driver from behind the wheel, AVs are expected to eliminate most of the 93 per cent of collisions that currently involve human error.

It then proceeded to calculate the economic benefits of such a change without claiming all 93% would be eliminated but also without considering the many inherent failures and shortcomings that could be introduced by errors in design of hardware and software, nor by the expectable failure rates of electronic components and assemblies.

The 93% has been popular with advocates of AVs, in good faith since the report referenced the source authoritatively as:


Following up this reference results in several documents that include cautions against exactly the kind of conclusion that has been perceived perhaps unjustly as drawn by Gill et al.

Before dealing with the specific numbers and documents, it should be noted that the National Motor Vehicle Crash Causation Survey (NMVCCS) was based on a sampling of collisions in certain states reported to the police authorities and investigated in depth on a basis representative of the national occurrences of collisions and then adjusted to scale back to the national situation in terms of accident type, location, etc. The survey was undertaken beginning in 2005 and reporting in 2007.
Furthermore, there are several facts which mean that the NMVCCS cannot be directly applied to AVs, to current or future traffic conditions, nor to European and specifically UK circumstances:

- NMVCCS was many years before widespread and mandatory adoption of antilock braking systems (ABS) in USA, although there were regulations governing ABS if fitted. Unlike existing European regulations, which had ABS and were beginning to make Electronic Stability Control (ESC) mandatory on all passenger cars, one-axle were permitted for USA ABS systems, which was counterproductive in some situations such as single vehicle loss of control, pickup trucks and SUVs, leading to resistance to adoption of ABS in the USA market\(^{5,6}\). Therefore the accident rates and types are not transferable to current markets where ABS and ESC are mandatory on most classes of vehicle.

- Urban, suburban, interstate, rural main and minor roads and tracks are all built, signposted, maintained, controlled and used differently from European and specific UK equivalents, leading to a different distribution of accident types and severities such as urban side impacts and road departure and rollover propensity. Prospectively, this could affect differences in the attraction of AVs of different categories in respective markets in combination with settlement patterns.

- Vehicle mix was and still is, different in the North American and European parc, again leading to a different distribution of accident types and severities such as SUV/truck into passenger car side impacts, more extreme vehicle sizes and masses, and rollover propensity.

- Regulations on vehicle roadworthiness inspections vary across the USA affecting vehicle condition and accident involvement.

- USA state driving licenses and tests have different requirements, as well as different controls on driving with use of alcohol, prescription and illicit drugs.

The data most commonly referenced from the NMVCCS comes from a recent document\(^7\) focusing on one aspect, the ‘Critical Reasons for the Critical Pre-Crash Event’:

“The critical reason is the immediate reason for the critical pre-crash event and is often the last failure in the causal chain of events leading up to the crash. Although the critical reason is an important part of the description of events leading up to the crash, it is not intended to be interpreted as the cause of the crash nor as the assignment of the fault to the driver, vehicle, or environment.”

This alone means that the data cannot ascribe “human error” as being categorically the cause of an accident in the way that the report of Gill et al\(^4\) has been understood. The methodology in fact considers a range of contributory factors that cause the situation where a crash can finally avoided by a single critical reason. That means that a human driver fails to extricate themselves an almost inevitable crash scenario in almost every case, as opposed to the vehicle or environment being
responsible. It is difficult to conceive otherwise, apart from falling trees, collapsing bridges or road surfaces.

So immediately after the above quotation, the summary states:

“A critical reason can be assigned to a driver, vehicle, or environment. Normally, one critical reason was assigned per crash, based upon NMVCCS researcher’s crash assessment. The critical reason was assigned to the driver in an estimated 94 percent (±2.2%) of the crashes (Table 1). In addition, the critical reason was assigned to the vehicle in an estimated 2 percent (±0.7%) and to the environment in about 2 percent (±1.3%) of the crashes.”

While “93%” appears nowhere, it is accompanied by a table in which vehicles, environment and unknown critical reasons were all assigned 2% (with different confidence limits):

Table 1. Driver-, Vehicle-, and Environment-Related Critical Reasons

<table>
<thead>
<tr>
<th>Critical Reason Attributed to</th>
<th>Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
</tr>
<tr>
<td>Drivers</td>
<td>2,046,000</td>
</tr>
<tr>
<td>Vehicles</td>
<td>44,000</td>
</tr>
<tr>
<td>Environment</td>
<td>52,000</td>
</tr>
<tr>
<td>Unknown Critical Reasons</td>
<td>47,000</td>
</tr>
<tr>
<td>Total</td>
<td>2,189,000</td>
</tr>
</tbody>
</table>

*Percentages are based on unrounded estimated frequencies
(Data Source: NMVCCS 2005–2007)

Understanding the full implications requires deeper analysis of the all the data in the full Report to Congress in which the total number of factors will be much more than the number of cases, and normalises them to 100% to show the relative role, the picture is very different:
This immediately highlights that taking the driver out of the loop has far less potential than 93% to affect the incidence of collisions and that far more weight must be attached to the vehicle, road and weather. Adding systems to a vehicle will bring their own failure modes and rates which must at least be compensated by improvement to the vehicles themselves (probably well in progress since 2005-2007) and that the systems must be better than humans in handling road and weather extremes, which currently they are not.

Having implied above that it is unwise to apply USA data directly to UK conditions, one should also apply recent causation data from DfT Road Accident GB\(^9\) collected with the STATS19 system with the proviso that:

"It is important to note that it may be difficult for a police officer, attending the scene after an accident has occurred, to identify certain factors that may have contributed to a cause of an accident.

The contributory factors are therefore different in nature from the remainder of the STATS19 data which is based on the reporting of factual information. This should be kept in mind when interpreting the data."

The table below summarises the details normalised to all accident total cases, with rounding errors

<table>
<thead>
<tr>
<th>Contributory Factor (UK)</th>
<th>All Accidents, normalised %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road environment</td>
<td>8%</td>
</tr>
<tr>
<td>Vehicle Defect</td>
<td>1%</td>
</tr>
<tr>
<td>Driver</td>
<td>75%</td>
</tr>
<tr>
<td>Error or reaction</td>
<td>41%</td>
</tr>
<tr>
<td>Injudicious action</td>
<td>13%</td>
</tr>
<tr>
<td>Impairment or Distraction</td>
<td>7%</td>
</tr>
<tr>
<td>Behaviour or inexperience</td>
<td>14%</td>
</tr>
<tr>
<td>Vision Affected by external factors</td>
<td>6%</td>
</tr>
<tr>
<td>Pedestrian only</td>
<td>7%</td>
</tr>
<tr>
<td>Special./other</td>
<td>5%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>
Although categorisation differs, it can be seen that the UK data does not reflect the USA data. The strict category Driver Error only accounts for 43%.

Many of the statements in this response below take into account these statistics of contributory factors to collisions as background; the source data do not always bear out the conclusions often attributed to them.

It is however clear that there are many other important factors that will prevent the dramatic improvements promised to AVs and ADAS by taking the driver out of the loop based on existing data, quite apart from the many new uncertainties introduced by known and unknown system inadequacies.

Policy decisions may need to be influenced by these data, particularly the necessity of improving safety for both human drivers and AV in the short and medium term by infrastructure and enforcement expenditure

1. Thomas, Alan V; Reality is not ideal: Autonomy and Driver Assistance challenges; Autonomous Vehicle Test & Development Symposium, Stuttgart 16-18 June 2015
2. Bham NEC
6. “Cars with antilock brakes are no longer overinvolved in fatal crashes”, Status Report Vol 35, No. 4, Insurance Institute for Highway Safety (IIHS), Highway Loss Data Institute (HLDI), Arlington VA., USA, April 15, 2000

Impacts and benefits

1. What are the potential applications for autonomous vehicles? 
   The largest potential may ultimately be in Mobility-as-a-Service, short of full replacement of all-purpose personal transport, but earlier successful
implementations are more likely in geo-fenced mobility and materials handling because these applications are in environments that are easier to predict and control.

By the same token these may be followed by freight and logistics on fixed, regular routes using platooning, and where payload and operating costs can be improved by reducing some or all provision for a human driver such as sleeper cabs. In that phase there may be issues with use of ad-hoc alternative routes for such vehicles in the event of road closures or severe weather limitations of the sensor technologies and heavy goods vehicles not carrying a human driver may have to be parked somewhere until they can be re-mobilised appropriately.

2. What are the potential user benefits and disadvantages from the deployment of autonomous vehicles?

3. How much is known about the potential impact of deploying autonomous vehicles in different sectors?

   One wonders how much is based on thorough consideration of all the positive and negative impacts of the use of autonomous vehicles in any sector: much of the information appears to derive from optimistic promotion of the technology or pessimistic critiquing.

   This will rapidly become evident in either direction now that such vehicles are being tested in more varied situations such as the UK, and equally while partial (ADAS, SAE L2-L3) systems are rolled out on the market. While not confusing L2 and L3 with L4 and L5, much of the basic technology is the same but less comprehensive and theoretically more prone to restricted situational awareness.

   More research and far more data capture is required in order to provide definitive answers to this question. This is unlikely to be achieved without recording and self-reporting of all traffic conflicts as well as just those resulting in collisions. This will involve complex issues of data ownership and privacy in incidents that do not currently warrant insurance or police attention which currently put data into third party organisations in the case of property damage or personal injury.

   At present, any lessons learnt from sensor, algorithm and actuator shortcomings in traffic by vehicles operated by the general public are, if captured at all, retained in corporate knowledge based, most notably by Tesla. Only in serious cases does the fact of an incident become public, and even then no verified detail of design or operation of the systems emerge in a timely fashion.

   In conventional vehicles a gradual accumulation of safety knowledge and application of technology over decades has enabled steady decrease in casualties (until very recently despite increasing traffic densities, speeds, and necessity of driving for people) who otherwise might have had no interest and motivation to become skilled. The changes and timescales now occurring are showing signs of
outpacing the ability of the authorities to respond with necessary measures or approval.

4. How much is known about public attitudes to autonomous vehicles?
What surveys there have been may be questioned on the grounds of how accurate the public’s perception of what is meant by autonomous vehicles, their capabilities, limitations of their technologies, and any required inputs from humans (at L4).

5. What is the scale of the market opportunity for autonomous vehicles?

Creating an enabling environment
Research and development

6. Is the scale of current and planned demonstration facilities for autonomous vehicles sufficiently broad and ambitious?
As first steps, yes. However, until the vehicles can be assured of handling all conceivable situations at least as well as a skilled and experienced human driver beyond reasonable doubt, the answer remains qualified. It must not be overlooked that due to extraneous circumstances such as emergency motorway or urban route closure anything less than a 100% L5 vehicle must be able to operate “off-piste” safely without inconveniencing other road users unless full licence holders must always be in the vehicle, thereby undermining some of the attraction of autonomous vehicles.

7. Is the Government doing enough to fund research and development on autonomous vehicles, and to stimulate others to do so? Should it be doing more to coordinate UK actions?

8. How effective are Innovate UK and the CCAV in this area?

9. Is the environment for small and medium-sized enterprises (SMEs) working in this sector sufficiently enabling?

Real world operation

10. Will successful deployment of autonomous vehicles require changes to digital or physical infrastructure?
Referring to the answer to Q6, and based on the demands from some quarters for a minimum standard of infrastructure such as road markings and infrastructure-to-vehicle I2V services, a massively great deal more needs to be spent on upgrading all classes of road and communications, including standardisation of road layouts, traffic control, etc. in urban canyons, tunnels and remote rural areas. The likelihood of continual software and hardware updates and obsolescence make the cost of ensuring no critical mismatch between all vehicles and all infrastructure, i.e. full backward and forward compatibility, near prohibitive.
Paradoxically, such improvements to the road and traffic systems will improve the safety performance of drivers of conventional vehicles, thus eroding the safety case often made for autonomous vehicles, quite apart from the current proven beneficial application of L1-L2 technologies such as AEB. Expenditure on infrastructure measures that improve human performance could be seen as an immediate priority that will reduce incidents in both the short term and the long term when autonomous vehicles become a significant proportion of the vehicle park.

11. How might a move from current levels of highly automated vehicles to their extensive deployment best be managed? What do you see as the key milestones?

The transition needs to be made with considerable caution, and evidence of satisfactory performance of each system in terms of designed capability and fail-safe in all possible failure modes whether internal to hardware and software or occurrence of out-of-scope scenarios.

The long gestation and acceptance of systems such as steer-by-wire and brake-by-wire up to the current levels in highly automated vehicles has given guidance as to how to approach design, development, testing and approval, but does not give licence to rush the process with higher levels of dependence and integration which have immensely higher complexity and propagation of undesirable behaviours.

12. Does the Government have an effective approach on data and cybersecurity in this sector?

It is doubtful whether anyone has an effective approach currently. Certainly enough partially attacks on IT systems have produced evidence of inadequate cybersecurity and immunity to external factors within the general IT world. The culture in automotive IT needs to be distinct and guided more by military and aviation levels of protection than some, not all, current implementations.

There are many levels that need to be considered here along with appropriate countermeasures:

- Cybersecurity in terms of prevention of access to sensitive data on the use of the vehicle i.e. related to personal privacy – journeys undertaken, etc.
- Cybersecurity in terms of immunity to deliberate subversion of software or data to affect the performance of the vehicle, and by implication its safety whether with malicious intent, curiosity, and tuning or “chipping” to modify performance, by remote or physical access to the systems.
- Cybersecurity in terms of immunity to deliberate subversion of software or data to affect the control of its routing, for instance for criminal or terrorist purposes such as delivering drugs, firearms or explosives as a car bomb, kidnapping, driving into crowds of people, etc.
- Functional Integrity which should be assured by correct application of ISO 26262 standards of safety-critical examination of data paths and inputs versus required outputs, but this depends on comprehensive understanding
and coverage of all potential inputs and all desired and undesirable outputs.

- **System integrity** – immunity to both software and hardware failure in design or service using multiple active redundancy (not just passive fallback), graceful decline, controlled handover to trained and competent humans and other aviation concepts. There is less discussion of these risks, but recent recalls of existing vehicle for control and sensor systems faults has displayed their existence. The ubiquity of consumer electronics devices with a limited battery life and short product life cycles with constant addition of new features leading to less concern over consumer tolerance fault, durability and replacement is at odds with the security and functionality needs of automotive electronics and software. The involvement of the manufacturers of consumer devices in automotive systems may need strict certification procedures for a large number of criteria.

- **Access to the vehicle systems** is required for diagnostics and upgrades which represent a definite vulnerability as the means of interfacing will be quite widely available and understood.

- **There is interest in law enforcement access to autonomous vehicle systems by police, local authorities etc. both retrospectively for criminal and collision investigates and in real time for enforced control, quite apart from I2V and V2V traffic control, parking and other non-moving infringements such as taxation and insurance. These are all vulnerable channels for fault propagation, tampering and criminal interference.**

13. Are further revisions needed to insurance, regulation and legislation in the UK to create an enabling environment for autonomous vehicles?

14. What, if any, ethical issues need to be addressed in the substitution of human judgement in the control of vehicles by algorithms and Artificial Intelligence?

   **Strict liability culture from automotive safety best practice rather than consumer IT and electronics.**

**Legal framework for courts and law enforcement**

**Wider governance**

15. What does the proposed Modern Transport Bill need to deliver?

16. How effective is the UK’s education system in delivering people with the right skills to support the autonomous vehicles sector?

   **More interdisciplinary at secondary and tertiary level for both design and development engineers and technicians as well as technicians to support service, repair and recovery businesses**

17. Is the Government’s strategy and work in this area sufficiently wide-reaching? Does it take into account the opportunities that autonomous vehicles offer in a wide range of areas, not just on the road?
18. What are the implications of exit from the European Union for research and development and the autonomous vehicle industry in the UK? Are specific actions from the Government needed to support or protect the autonomous vehicles sector in the short term or after the terms of Brexit have been negotiated?

26 October 2016