

DEFINING & REGULATING AUTOMATED DRIVING

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ABSTRACT

The development of Automated Driving Systems is challenging international regulators to make change in order to determine how such systems may be legally sold and driven on our roads. Road safety is expected to be one of the main benefits of automation but it also offers the potential for significant new risks, particularly in the early stages. The insurance industry has a core interest in both the technological and associated regulatory changes because of their impact on liability, cost, and underwriting and has sponsored significant research activity to understand the issues.

Driver assistance systems that act in the brief moments before a collision, or to support and not replace driver inputs, are being progressively proven effective and full automation (SAE levels 4&5) is expected to be highly beneficial. However, where the driver is not needed for the driving task but must be capable of resuming control at any moment (SAE 3) considerable risks of public confusion and pricing difficulty have been identified. Modelling of crash risks suggests that the net benefits of such systems will be positive but that significant risks remain. This would support a binary definition of Automated Vehicles at SAE level 4 and above. Anything at level 3 or below would be considered Assisted Driving where the driver remains responsible for safe operation. It is considered that to avoid becoming a barrier to positive changes, developing the requirements for automated vehicles should commence now. In the short term, the development of requirements related to assisted highway driving at SAE level 2/3 should continue with the aim of maximising safety benefits as well as minimising risks. The latter may require full driver monitoring systems rather than simple measurement of whether driver's hands are on the wheel. Consideration should be given to creating a separate regulation integrating requirements for assisted and autonomous driving as well as to the implementation of different regulatory approaches, potentially including elements of self-certification. The aim should be to maximise the speed and flexibility of the regulatory process while providing clear, coherent and robust requirements.

INTRODUCTION

The development and availability of Automated Driving Systems is challenging International regulators to make change in order to determine how such systems may be legally sold and driven on our roads. The insurance industry has a core interest in both the technological and associated regulatory changes because of their impact on liability, cost, and underwriting.

Road safety is expected to be one of the main benefits from automation but it also offers the potential for significant new risks, particularly in the early stages. Most commentators agree that full automation (SAE level 4&5) has the potential to substantially reduce collisions. Pre-crash driver assistance systems act only in the moments before an imminent collision (SAE 1&2) and there is ever growing evidence of the casualty reduction effectiveness of this type of system. However, there is also a growing body of research evidence identifying significant risks associated with driver assistance functions that take control over large parts of the driving task while still requiring the driver to monitor the road or at least to become a redundant fall back in any situation where the system cannot cope (SAE L2/3).

Regulators in Europe are currently working on amending existing regulations to explicitly permit and control this latter form of driver assistance. The aim of this paper is a preliminary exploration of the risks and benefits of the technology and how this relates to regulatory amendments already under discussion and others that may be required in future.

UNECE REGULATION 79

Currently, UNECE R79 governing steering systems forms a barrier to the sale of higher levels of automation in Europe. It defines different categories of steering automation:

- Driver assistance (ADAS) steering
 - Corrective steering
 - Automatically commanded steering function (ACSF)
- Autonomous steering

ADAS steering can rely only on signals generated on-board the vehicle and is permitted in the circumstances defining corrective and automatically commanded steering functions. For corrective steering the automated input must be discontinuous and of short duration, well matched to the characteristics of a basic lane keep assist system. An ACSF can be a continuous function but is only permitted at speeds of up to 10 km/h, well

matched to the characteristics of basic parking assist systems. In practice, the definitions are such that it has proved possible to approve a range of systems that are considerably more advanced than the simple examples likely to have represented the original intent. These include systems capable of continuous high speed lane centring and even automated execution of a lane change commanded by the driver.

Any system that uses signals generated off-board the vehicle are classed as autonomous steering and are explicitly prohibited.

An informal UNECE committee began work on amending R79 in relation to automated steering in April 2015. During this process a series of new categories of steering assistance have been defined (UNECE, 2017):

- Corrective steering function: a limited duration input e.g. to improve stability in side wind
- ACSF A: low speed assistance e.g. parking
- ACSF B1: assisting the driver to keep in lane
- ACSF B2: system that can keep the vehicle in lane for extended periods without driver intervention
- ACSF C: auto execution of a single lane change requested by the driver
- ACSF D: system that identifies opportunity for lane change, and if confirmed by the driver, executes it automatically
- ACSF E: Once activated by driver, capable of keeping the vehicle in lane and executing lane changes as and when required without further driver input.

It is envisaged that the B2 category can be combined with categories C to E, such that an individual system might be category B2C or B2E.

The work on defining the requirements for various categories has been split into stages.

Stage one: CSF, ACSF A & B1

Stage 1 provided new definitions and requirements for corrective steering and ACSF category A & B1. It is essentially complete and is expected to enter into force by September 2017. In summary, these amendments clarify and strengthen the requirements related to systems such as remote parking and lane keep assist systems. The former is permitted provided the remote function is based on a 'deadmans handle' principle and operates only over a limited range. The latter are permitted

providing the system detects whether the drivers hands are on the wheel and warnings are issued if there are no hands on for 15 seconds. The warnings escalate such that if no hands are detected on the wheel for a whole minute, the system is deactivated.

Stage 2: Category B2, C, D and E

Discussion of the requirements for stage 2 systems began in parallel with those for stage 1 but development was suspended to allow the early completion of stage 1. Work resumed on stage 2 in March 2017 and it has been proposed (OICA, 2017) that this work should be complete by March 2018 which would mean that it could enter force ready for first approvals in early 2019.

The systems covered in this stage begin with those with functionality similar to the Tesla AutoPilot and Mercedes Drive Pilot, which will undertake prolonged lane keeping functions and execute lane changes on command. However, it also extends to future systems capable of both identifying the need and opportunity to change lanes automatically and executing the manoeuvre without further driver intervention. The basic remit of the group has been to only consider systems at SAE level 2 where the driver remains responsible for monitoring the road environment at all times (described as “hands off but eyes on”). However, industry anticipate (OICA, 2017) that this remit will be expanded to add systems at SAE level 3 where the driver only needs to be available as a redundant back-up in the event of a problem or a situation the system cannot deal with.

The requirements for this stage are still under discussion and a variety of proposals have been made¹. These have included:

- Restricting to roads of motorway standard only
- Keeping hands-off warnings at 15 seconds
- Extending hands-off warnings to 3 minutes
- Replacing hands-off warnings with driver monitoring (i.e. hands can be off as long as eyes and brain are on)
- Capability for emergency manoeuvre in the event of sudden hazard ahead: AEB from 130 km/h and/or lane change
- Capability of a minimum risk manoeuvre in the event the driver drops out of the loop: Progressive stop in lane or safe stop at side of road.

¹ For details see <https://www2.unece.org/wiki/pages/viewpage.action?pageId=25265606>

Draft test procedures have been considered for some elements of performance but, at this early stage, many aspects still lack technical detail in definition, requirements and test methods.

Stage 3: full automation (level 4/5)

At the time of writing, stage 3 had not yet been defined and no timetable had been produced. However, appropriate requirements are needed for systems sufficiently robust for the driver not even to be required as a redundant backup, only to continue the journey once the end of the operational design domain has been reached.

IDENTIFYING THE RISKS AND BENEFITS

Risks

It is now well documented that the road to fully automated vehicles carries some risks that crashes may occur as a consequence of automation. In other words, crashes that would not have occurred if the vehicle had been driven manually. The concern around this focusses mainly around SAE level 2 and 3 systems that take over large parts of the physical control task from the driver, but still require the driver to monitor the environment constantly (level 2) or at least to be capable of resuming control at any given moment (Level 3). The theory is that the less the driver is fully engaged in the control of the vehicle, the more easily distracted they become and the more disengaged they become from the environment, making it difficult for them to identify risks that the system may miss, or to resume control when required. A long history of automation in aviation would tend to back up that theory and a range of human factors experiments confirm varying degrees of impairment as a result of lack of engagement in driving (see for example, (Merat & Jamson, 2009) (Jamson, et al., 2014) (Young & Stanton, 2007)).

(De Winter, 2014) shows that compared with drivers of a manual car, drivers operating ACC and highly automated driving systems were much more likely to undertake a secondary task. Further, (NTSEL, 2016) have shown that drivers of highly automated vehicles not engaged in a secondary task are much more likely to become drowsy than drivers of manual vehicles. The most affected subject in this experiment started to show signs of drowsiness after just three minutes.

Other authors have considered the response of the driver of an assisted vehicle to requests to take over the driving in response to a variety of situations. The results vary considerably. For example, (Gold 2013) suggested that providing a takeover request 5 to 7 s in advance ensures that drivers of a high

automated car avoided stationary objects. (Jamson, et al., 2014) found that the time required to regain control after a transition request was 10-15 seconds and it could take as long as 45 seconds for behaviour to fully normalise.

However, there are also examples of research showing similar response times to critical events. For example, (Kircher, et al., 2014) found that in response to critical events such as a broken down car, a curve event and an exit event, drivers behaved intelligibly resuming control where necessary and leaving the automation in control where not. (Merat, et al., 2012) found that where drivers were required to change lanes to negotiate past a hazard in the lane ahead, then there was no difference in performance between manual and highly automated driving provided the drivers were not distracted by a secondary task. (De Winter, 2014) summarised the complex evidence as suggesting that if drivers remain motivated in highly automated driving then their spatial awareness can improve relative to manual driving. If they become drowsy or are distracted by a secondary task their spatial awareness will be degraded. The evidence suggests that in the absence of measures to prevent it, the drivers of highly automated vehicles are more likely than drivers of manual vehicles to become drowsy or to be distracted by secondary tasks.

(Edwards, et al., 2016) studied how regulatory proposals controlled for some of these risks. They found that hands-on detection left room for potential abuse of SAE level 2 and 3 systems. That is, it did not represent a good proxy of the drivers state of spatial awareness as considered by (De Winter, 2014).

Almost all of these studies have been undertaken in driving simulators of varying fidelity and this does introduce significant limitations about, for example, how well they represent the real function and reliability of automation, the HMI that will actually be employed in production vehicles and, generally, the differences between driving a simulator in an experiment and driving in real life. It may be notable that none appear to directly simulate responses in the type of conflict resulting in the first documented fatality involving mis-use of an SAE level 2 assistance system (NHTSA, 2017).

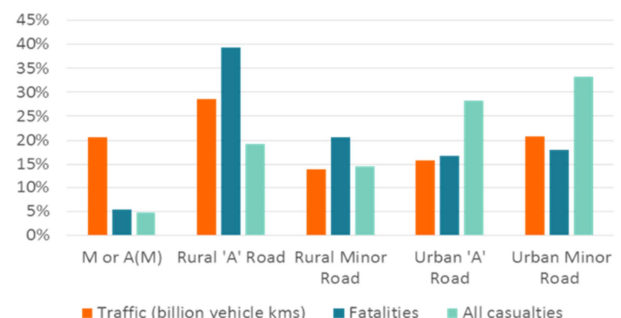
Benefits

The safety benefits of automated driving are often simplistically associated with the well quoted statistic that human behaviour contributes to 90-95% of crashes. Whilst broadly correct, it is important to note that some of the humans contributing to the causes of those crashes do so as

pedestrians and pedal cyclists, and these contributions will not be directly affected by the automation of road vehicles. Despite the fact that the road vehicles may get better at compensating for the errors of pedestrians or cyclists, it is apparent that even full automation will not necessarily eliminate all casualties related to human error.

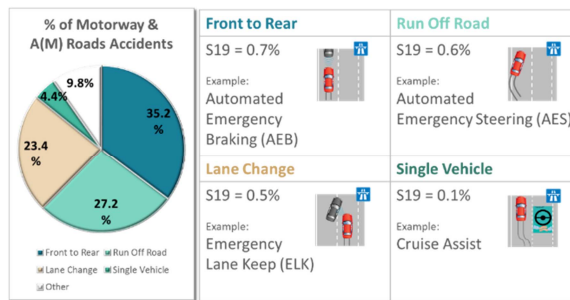
When considering the developments that will fall within the scope of the second stage of UNECE regulatory amendments, it is apparent that they will be most commonly used on Highways and, in Europe at least, may be restricted by Regulation to work only on roads of Motorway standard (divided carriageway, no pedestrians, no cyclists, no cross road junctions etc.). These are the least complex road environments and analysis of traffic and accident data suggests that this reduced complexity does indeed translate to a reduced collision risk. In GB, 20% of all vehicular traffic (vehicle km's) is carried by motorways, but just 5% of casualties and 5% of fatalities occur on these roads (see **Figure 1**).

Figure 1: Traffic and casualties by road class.
Source: UK Government statistics



Highly assisted driving will not be mandatory; it will be the driver's choice to switch it on or not. So, even when vehicles are equipped, not all motorway travel will be undertaken with the assistance activated. Combined with the fact that the environment that it can currently be used in experiences only around 5% of crashes, this limits the crash prevention potential. The types of crashes that occur on motorways are examined in more detail in **Figure 2**, below.

Figure 2: Collision types relevant to Motorway Assist technologies. Source: Stats 19



It can be seen, for example, that front to rear collisions make up 35% of those crashes that occur on Motorways. In a Motorway Assist or automation mode, the AEB on a vehicle will be able to stop the vehicle from higher speeds than normal AEB because there will not be a concern about annoying a driver who was about to manually change lane (for example). The driver has already relinquished control to the vehicle and should not, therefore, be annoyed by a much earlier intervention. Thus, motorway assist should be highly effective at reducing front to rear collisions on the motorway. However, this translates to just 0.7% of all injury crashes reported to the police, so the maximum impact of the additional benefit of the automation is limited.

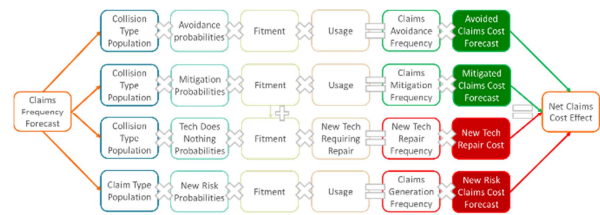
Although the direct safety benefit of the motorway assist type of technology may be limited, the sensors and algorithms required to enable it can be used for other activities. Studying the new vehicle market shows that vehicles with high levels of assistance in normal driving (e.g Mercedes, Tesla, Volvo) are also coming with a wide range of emergency assistance features that are not active in normal driving, but which do intervene in the moments just before a collision. Several of these technologies, particularly AEB have been shown to be highly effective at reducing crash frequency, see for example (Doyle, et al., 2015) (Fildes, et al., 2015) (HLDI, 2015). These can be considered to form a technology ‘Safety Net’ that will typically work on all types of road in a diverse range of collisions. They usually default to being switched on all the time. Thus, they have the potential to influence the 95% of injury crashes that occur off the motorway network and are likely to be very effective.

QUANTIFYING THE RISKS AND BENEFITS

In order to inform the UK insurance industry of the possible impact of increasing levels of automation, Thattham Research has created a complex predictive model, known as the ‘Claims of the Future’ model. It covers a wide range of technologies and different impacts on claims, not

just casualty reduction. The basic structure of the model is shown in Figure 3, below.

Figure 3: Basic structure of calculations in the Thattham ‘Claim of the Future’ model



Casualty Reduction Potential

The first two lines of the structure above relate to predictions of the casualty reduction potential of different technologies. They begin with a forecast of ‘business as usual’ casualty trends if no new technologies were introduced. This is divided into different crash types that might be affected differently by different technologies. Samples of in-depth casualty data are used to further divide the crashes into different categories (e.g. road class, speed, weather and lighting conditions etc). The characteristics of each technology system are then mapped onto this complex matrix of crash types to see which of them the system would be likely to avoid, mitigate, or do nothing for. From this, the potential casualty reduction can be calculated. This is factored by estimates of the likely fleet penetration of each technology in any given future year and estimates as to what proportion of time the driver will choose to use the system. The resultant estimate of casualty reduction is subtracted from ‘business as usual’ forecasts to produce the estimated effect.

Of the technologies considered within scope of the model, only AEB has large quantities of post-hoc statistical measurement of its real world effectiveness. This is partly because newer technologies may not yet have sufficiently penetrated the fleet to reach significant results. However, it is also partly because newer technologies are often sold as part of a package of different technologies, not as a single system such that it is becoming harder to measure their effects separately.

A wide range of studies have been undertaken and almost universally show very positive benefits of AEB, though the exact magnitudes vary quite widely depending on individual study controls, vehicle makes and models compared and whether comparisons are based on insurance claims of different types, frequencies and cost or based on police reported injury crashes. Thus, AEB was used as a candidate technology to calibrate the predictive methodology. It was found that the predictive

method forecast an effect that was towards the low end of the range measured by post-hoc statistical surveys. It was, therefore, considered to be appropriately conservative.

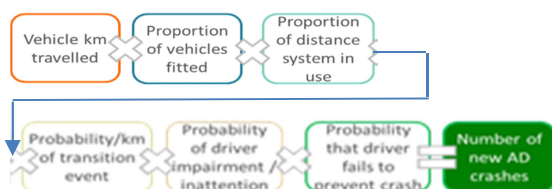
When all technologies in scope are considered, the model predicts that by the year 2030, overall insurance claims frequency will be between around 15% and 25% lower than it would be if these new technologies were not being introduced.

New risks Model

Claims of the future covers a range of ‘new risks’ associated with automation, including items associated with repair of sensors, or the effect of camera recalibration requirements on windscreen replacement claims etc. This paper considers only the elements relating to the chances of collisions occurring with level 2 or 3 systems that would not have occurred if the driver had been driving manually.

A predictive model was used, in a similar way to the casualty reduction model and the basic calculation is highlighted below.

Figure 4: Illustration of calculation of likely collisions as a consequence of drivers performing poorly when supervising level 2 automation or when acting as redundant backup with Level 3 systems.



The range of situations, failures and other factors considered within the model are illustrated below

Figure 5: Input parameters assessed within the driver behavioral ‘new risk’ model



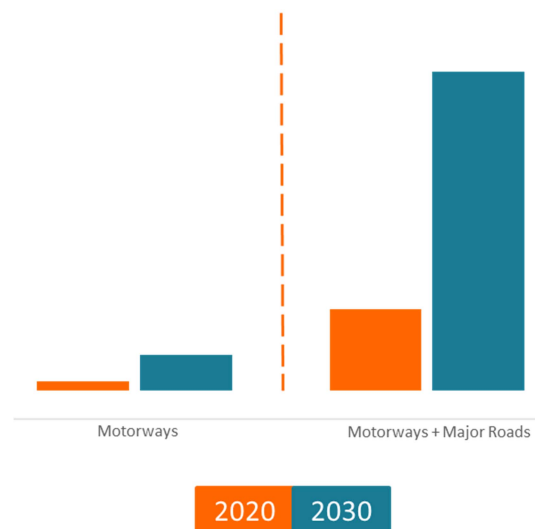
The creation of this model provides the functionality to allow the magnitude of the possible impact of new risks to be explored. However, at this stage the input evidence available is limited by

the fact that few systems are in production, in low volume vehicles only and the detailed results of trials are typically not publicly available. Thus, the absolute magnitude of results remains uncertain but the sensitivity analysis and preliminary conclusions provide valuable early insight. At this stage, the input evidence has been based on a variety of sources, including:

- Vehicle travel data by road type
- Current collision rates per vehicle km for relevant classes;
- Typical failure rates for safety critical electronic components;
- Simulator studies and other human factors experiments;
- Publicly available data on transition requests from trials e.g. (Google Auto LLC, 2015);
- Proportion of manually driven collisions where certain situations/features were present.

Indicative results from the model are shown below.

Figure 6: Indicative estimate of new crashes with level 2/3 assisted driving technologies that would not have occurred if the vehicle was manually driven.



Discussion of risks and benefits

In absolute terms the forecast number of new crashes was small and the number of crashes prevented by the associated ‘Safety Net’ of pre-crash safety technologies was an order of magnitude higher. Thus, it is expected that the net benefit of Level 2 and Level 3 assisted driving technologies should be overwhelmingly positive.

However, aside from the positive net effect, the analysis suggests a range of risks. In particular, if a vehicle becomes stationary in lane on a high speed road because a driver has failed to respond to a takeover request, then there is clear potential for catastrophic claims. As well as the obvious risks to the individuals involved and their families, these have the potential to be extremely damaging to the reputation of vehicle automation and can cause significant damage to the individual insurer held liable. In addition to this, the wide range of different approaches and the highlighted importance of HMI could make it very difficult for insurers to accurately price risks.

Another important caveat in this analysis is the input data in relation to the market penetration of assisted driving technologies at SAE level 2 and 3. As things stand, the use of Level 2 systems such as Mercedes Drive Pilot or Tesla's Autopilot require the driver to monitor the environment constantly. There is a reduction in the driver workload and, therefore, potentially their stress level. However, it is not legally permitted to use a hand held phone or to be distracted from driving in any other way. Given that the systems are expensive optional extras, there is a limited incentive to purchase them.

Once systems are introduced at SAE level 4 and above, it is expected that it will become legally permissible to undertake secondary tasks at the wheel. This allows drivers either extended leisure of working time, which they are expected to value highly. Thus, there will be considerable incentive to pay for the systems.

At SAE level 3, the model has assumed that the same limitations on driver activity will be applied as for Level 2. Thus, it is also assumed that the commercial purchase incentive will remain limited and that level 3 systems will form a technological stepping stone to Level 4. Thus, it was forecast that the market penetration of level 3 systems will remain relatively low, never reaching anything near 100%.

If these assumptions were to prove incorrect, for example if regulators permitted secondary tasks while driving a level 3 car, or if the additional cost of moving to level 4 proved prohibitive, then market penetration of level 3 technologies would be expected to greatly exceed the currently forecast levels. This would substantially change the predicted absolute number of additional crashes as a consequence of the identified behavioural risks.

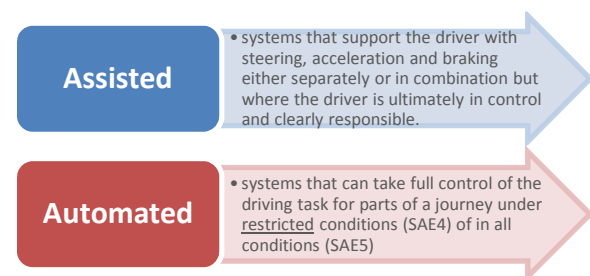
IMPLICATIONS FOR REGULATIONS

Defining Automation

There is clear evidence from the human factors research reviewed and the extensive recent media coverage of automated vehicles that the driving public could become confused as to the capability of any vehicle which they are driving. Although initial analysis suggests that the benefits of SAE level 2 and 3 technologies are likely to outweigh the risks, this evidence suggests that there would be considerable merit in providing a clear definition of automated vehicles.

The SAE definitions (SAE, 2014) are very useful for engineers but have not been considered appropriate for use in UNECE Regulations. There, 8 categories of different steering automation have been defined. It is considered that both of these sets of definitions are too complex for the avoidance of risks arising from driver behaviour. When communicating important messages to the public it is important to keep things simple. A binary approach to the definition of automation would, therefore, have clear advantages for the driving public, insurers and regulations relating to vehicle usage. This is illustrated at a high level in **Figure 7**, below.

Figure 7: Illustration of a binary definition of vehicle automation.



The essential public message here is that a vehicle is not capable of automated driving until it is legally permissible to ignore the driving task completely, at least for defined sections of the journey. Any other system should be considered, irrespective of how it is marketed, to be Assisted Driving only. However, this will require a technical definition of automation that can be used by regulators and meet the needs of insurers and other stakeholders. Some key requirements of this definition have been identified during the course of the analysis but may not be exhaustive at this early stage:

- A safe system of operation must be supported. The system must be able to determine (utilising all the information available to it from on-board and off-

board sources) in what circumstances it is able to offer its driver an Automated Mode of operation, taking into account:-

- The environment in which it is operating (type of road, car park, private drive etc);
 - Traffic conditions, road pavement conditions etc.
 - Weather
 - Connectivity
 - Speed limit and/or average traffic speed
- A vehicle may offer one or more Automated Modes, for example, on Motorways and fully separated dual carriageways, low-speed urban roads, car parks etc. This should be defined by the manufacturer but enforced by regulation such that the system cannot be activated outside of those modes.
 - Engagement of an automated mode must go through a properly planned and executed “offer and confirm” process. Automated mode should only ever be engaged after the vehicle has understood the planned journey and/or parking manoeuvre and confirmed it is safe, where that Automated Mode will become available and where, if applicable, any handback to manual control will need to take place.
 - A vehicle must be able to deal with all situations it would reasonably be expected to encounter within the active Automated Mode, without monitoring or intervention from the driver. For example, on urban roads an Automated vehicle should be capable of dealing with all other road users. Whilst operating on a Motorway, it should expect to deal with pedestrians on the hard shoulder next to a broken-down car but not necessarily in a running lane.
 - As a minimum, a vehicle in an Automated Mode should enforce compliance with the designated speed limit. However, consideration could be given to introducing risk adaptive speed control. For example, when a vehicle is operating in a 30 mile/h limit but detects a large quantity of pedestrians on the kerb it might slow to 20 mile/h. By contrast, on a street where a 20 mile/h limit is posted (typically to improve pedestrian safety) at 4:30 in the morning where no pedestrians are detected in the vicinity of the vehicle, it might permit a speed of 30 mile/h. This would clearly require amendment of existing speed limit legislation.
 - Sufficient redundancy will be required to allow an Automated Vehicle operating in

an Automated Mode to fail in a safe manner. For example, if any one single part of the system fails (e.g. a single sensor, or connection to the cloud map) then there should be sufficient redundancy for the vehicle to safely complete the planned journey at least as far as a previously identified ‘safe haven’ (i.e. not just at the side of the road adjacent to where the failure occurred), possibly at reduced speed.

- For the avoidance of doubt, any human driver in an Automated Vehicle operating in Automated Mode shall **not** be considered a redundant system or solution.
- An Automated Vehicle may be certified as such at the point of initial deployment or following the introduction of a software or hardware upgrade that enables the functionality of a new or improved Automated Mode.

Regulations relating to vehicle use

Regulations and guidelines relating to the use of vehicle (for example, the Highway Code in the UK) will strongly affect how drivers perceive the technology that their vehicle offers. The concept of a binary definition of automation would be strongly reinforced if as few changes as possible were made to vehicle usage regulations for vehicles capable of assisted driving. Relaxations on requirements for hands to be on the wheel at all times, or the undertaking of secondary tasks would be reserved for Automated Vehicles meeting a regulated definition, as illustrated above.

Regulations relating to vehicle construction

SAE Level 4 Many of the economic and social benefits of assisted and automated driving will only be achieved when SAE levels 4 and 5 are reached. Volvo have publicly stated an aim to produce vehicles capable of L4 highway operation by 2020/21 and Ford and others are aiming to introduce L4 automation for low speed urban areas in a similar timeframe. Thus, amendments to permit these developments should be in place by early 2020 at the latest. However, Tesla have stated an aim to have L4 automation in production vehicles by 2018 and a variety of manufacturers have suggested automated valet parking systems will be in production in 2019/20. If these ambitious targets were to be achieved it would put the regulatory process under pressure to accelerate permission.

At the time of writing, the UNECE informal working group defining requirements was limited only to systems at SAE level 2. A proposal had

been made to expand to SAE level 3 systems but as yet, no firm proposals for a time frame for SAE level 4 had been defined. In order to avoid UNECE Regulation becoming a barrier to the level 4 technologies being proposed by industry, it appears essential that the process of formulating the appropriate regulations or amendments should begin as soon as possible.

SAE Level 2/3 The modelling of crash data and new risks shows that the ‘safety net’ of pre-crash safety systems are essential to the conclusion that SAE level 2/3 assisted driving technologies will produce a net casualty reduction benefit. This is principally because most of the technologies related to assisting normal driving will only influence the small proportion of crashes occurring on motorways and only when the driver has chosen to activate it. Pre-crash safety systems are typically active 24/7 on all road types and can benefit a much larger population of crashes. However, at present the inclusion of pre-crash technologies is at the discretion of the manufacturer. There may, therefore, be a case for mandating the inclusion of defined pre-crash functions wherever a vehicle is equipped with level 2/3 assisted driving functions.

In addition to this, the benefits of the technology could be further maximized if the systems, when activated by the driver, enforced compliance with the posted speed limit and safe following distances.

Controlling the behavioural risks at this level may be complex. As a minimum, the evidence suggests that the following technical requirements may be required:

- Systems shall be geo-fenced to enforce operation only on roads of Motorway standard
- “Systems must be able to automatically brake to a stop from 130 km/h or the maximum system active speed if a stationary vehicle is detected in the lane ahead or encroaching into its lane by a greater amount that it can safely avoid without itself exiting its own lane (the emergency manoeuvre).”
- The vehicle will monitor the driver’s hands on the wheel. Initial ‘place hands on-wheel’ warning to be issued after 30s
- System deactivation should occur if hands-on is not detected, despite warnings, for 1 minute
- A ‘3 strikes and you’re out’ rule should be implemented to avoid driver abuse of systems
- The minimum risk manoeuvre should promote a safe stop if drivers become disengaged and the system deactivates. As

a minimum, this shall require the vehicle to pull over to the side of the road, as far out of running lanes as possible.

- “Limited system redundancy should be available. This should, as a minimum, cover sensors and should allow the system to safely operate in a “limp home” mode or to a “safe stop” in the event of a single sensor failure. Adequate warning of the situation should be given to the driver and a take back request issued.”

However, the evidence suggests that the hands-on restriction may well be insufficient to control the risks and, therefore, that more direct monitoring of driver alertness or readiness will be required. Technology to facilitate this does exist but the appropriate technical requirements will require significant research and development (Edwards, et al., 2016). Thus, they may not be available in the short term.

ONGOING CHALLENGES

The current regulatory changes are all being made within the steering regulation (UNECE R79). This risks too narrow a focus on only the steering aspects of systems. For example, there is no documentation suggesting that any requirement on speed compliance has been considered in R79 or whether there has been any consideration of whether a vehicle equipped with a motorway assist system should be obliged to have AEB and lane keep assist that operates on all road types, thus enforcing the ‘safety net’ concept. If such requirements were to be introduced within regulation 79 it would risk regulatory confusion where a steering regulation controls aspects of braking, driver monitoring, location services etc.

A separate regulation covering assisted and automated driving that integrated all aspects of its operation and referred to individual regulations on separate sub-systems, where necessary, would avoid this problem. However, the creation of such an instrument would take additional time and considerable time pressure already exists.

Creating the requirements for B1 steering systems and entering them into force will have taken around 2.5 years. An additional period of almost 2 years will elapse before the requirements relating to SAE level 2/3 Motorway Assist will enter into force. A range of other automation functions are conceivable:

- Motorway automation (SAE 4)
- Low speed urban assisted driving (SAE 2/3)
- Low speed urban automation (SAE 4) with steering wheels
- Low speed urban automation (SAE 4) without steering wheels

- Valet parking systems
- Non-motorway highway assisted driving (SAE 2/3)
- Non-motorway highway automation (SAE4)

While it may get easier to regulate new functions as time goes on because more will already exist, the complexity of different systems may also increase. If each function continues to be regulated in the same sequential, in-depth, manner before it is permitted on the road, then covering all of these functions could take considerable time. Based on a crude average of 2 years per function as approximately experienced in the latest amendments would see the process take 14 years. If this only started after completion of the current work, then the last amendment might not enter into force until around 2033.

Although the analysis of timing is extremely speculative, it does highlight the risk of the regulation becoming a barrier to progress rather than an enabler of progress. Not every regulatory regime is following the same approach, for example, the USA (NHTSA, 2016) does not currently prohibit any technology and has introduced an initial code of practice to begin controlling the risks. The US approach allows the manufacturer to self-certify that they are safe but actively monitors the safety of vehicles in use and can impose significant penalties if any defects in performance are found. A review of the advantages and disadvantages of different regulatory processes and principles may be required in order to both mitigate the risks of becoming a barrier to new technology and to further the harmonization of regulation globally. This should focus on extracting the best from each of the different approaches around the world and creating a system that enables innovation while minimizing risks.

CONCLUSIONS

1. UNECE Regulation currently forms a barrier to the sale of higher levels of automation in the EU. Amendments are underway but extend only as far as SAE level 2/3 systems for assisted driving on highways.
2. These systems have been shown to have the potential for an adverse effect on behavioural risks and this could translate to a significant risk of new crashes that would not occur during manual driving. These could be damaging.
3. Most of these risks are centred on the ability of drivers to maintain alertness and spatial awareness with the reduced workload implied by operating the system and/or abuse of the system.

4. The evidence suggests that as long as the risks are controlled and such systems are sold alongside a 'safety net' of pre-crash safety systems such as AEB or Emergency Lane Keep, the net effects will be overwhelmingly positive. However, there is no regulatory requirement for such systems.
5. As a minimum, controlling the risks should involve hands-on requirements, a 3-strikes and you're out policy to prevent abuse, the ability to execute a safe stop at the side of the road if the system is deactivated and to execute an emergency manoeuvre to avoid collisions.
6. Evidence suggests hands-on detection is a relatively poor proxy for driver alertness or spatial awareness and that driver monitoring technologies may be both available and more effective. The development of requirements will be a priority.
7. Current definitions of automated driving do little to avoid public confusion over the extent to which vehicles can 'drive themselves'. A binary definition of Assisted and Automated would help avoid confusion:
 - a. Automated Driving: where the driver is legally free to undertake a secondary task and pay no attention to the road when the vehicle is in charge (SAE 4 & 5)
 - b. Assisted Driving: All systems where the driver remains responsible for at least the function of acting as a redundant backup in the event of system failure (SAE 1, 2, & 3)
8. Regulations governing the use of vehicles should not be relaxed for Assisted Driving, only for Automated Driving.
9. The largest of the socio-economic benefits of vehicle automation will only be achieved at SAE level 4 and beyond. The current regulatory amendments will not permit level 4 vehicles and there is no activity currently underway to change this.
10. In order to avoid UNECE Regulations becoming a barrier to significantly beneficial technology:
 - a. Work to create regulations that permit SAE level 4 would need to commence as soon as possible.
 - b. Consideration should be given to separate regulations for assisted and automated driving that integrate the requirements on various aspects of performance

- c. Consideration should be given to the use, at least in part, of alternative regulatory processes including the use of guidelines and self certification.

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