



Commercial Vehicle On-Board Safety Systems

Summary and Conclusions

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Roundtable

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The International Transport Forum

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Executive summary

What we did

This report analyses the impacts of increased automation of the driving task for road freight transport. It investigates the technology options from platooning to full autonomy and examines necessary policy responses. Focusing on the underlying regulatory frameworks, it asks how existing approaches can be maintained and when and how novel solutions will be needed. The report summarises the findings of a Roundtable held in Washington, D.C.

What we found

Automation of road transport is now a clear trend. Many technologies that will be required for full automation (SAE level 5) are already being developed and tested globally. First use cases are emerging but their future deployment is still uncertain. Low-speed urban shuttles for shared mobility and automated trucks on motorways are among the most likely first implementations. The business case for automating road freight also points towards early adoption. However, fragmented regulations and lagging regulatory responses to technological developments require new solutions.

What we recommend

Focus regulatory attention on autonomous trucks as one of the likely early areas of vehicle automation

Regulatory attention regarding automated driving has focused too narrowly on passenger vehicles. Long distance road freight is one of the most likely initial applications of advanced vehicle automation technologies. It makes extensive use of inter-urban motorways, which provide a less complex environment than other roads. There is also a commercial incentive for automation of trucks. Labour costs constitute between 35%-45% of costs for long distance road freight in Europe. Automated road freight could also alleviate pressure from the persistent driver shortages in the United States and Europe.

Ensure international harmonisation of regulation for autonomous trucks

Harmonisation is more important for autonomous trucks than for other forms of automated driving. By its nature, long distance road freight crosses jurisdictional boundaries, both at Federal State borders and international borders. Thus multiple regulatory frameworks could apply on a single trip. Diverging regulations could thus require cross-border freight operators to install multiple on-board systems in their vehicles, or to change vehicles at jurisdictional borders. At worst, they could effectively prevent certain automation technologies from being used in particular jurisdictions. Thus, the 2015 “G7 Declaration on Automated and Connected Driving” notes that the full potential of autonomous vehicle technologies cannot be harnessed without a harmonised regulatory framework.

Use the flexibility within existing regulatory frameworks to accommodate vehicle automation technologies

Today's regulations can stretch to accommodate vehicle automation technologies to a certain point. Up to automation level SAE 2, technology assists rather than replaces drivers. Current regulatory frameworks are thus able to accommodate them. Existing road rules, vehicle standards and type approval processes can also handle this degree of automation relatively well. This provides a short window of opportunity for regulators to prepare for regulating higher levels of automation. Central concepts such as "driver" and "control" offer room for interpretation. The term "driver" for instance could evolve to mean not only a human, but potentially include multiple drivers or operating software. Some therefore consider that existing regulatory frameworks could accommodate technology up to SAE level 4, albeit imperfectly.

Weigh the advantages, disadvantages and limits to stretching existing regulatory frameworks to cover safe vehicle automation

Adapting existing frameworks may be preferable to creating new frameworks that may lock in a standard that is too high or too low. However, this carries risks. For example, the broadest interpretation of current regulations would view vehicles automated with SAE level 4 technologies as legal to operate on public roads today, despite safety concerns. Rather than the technological components, the difficulty is how to override automatic control safely at intermediate levels of automation where the driver remains ultimately responsible for safe operation. Under a permissive regulatory regime the potential backlash in case of a serious incident could halt development of automated trucking.

Consider data-led approaches for regulating vehicles with high automation levels

Applying a data-driven approach to regulating fully automated vehicles could provide a better governance framework for vehicle automation. It could potentially extend beyond type approval for ensuring safe operation of vehicles. Much of the underlying information required for regulating the various aspects of road-based freight transport relates to the geo-location of vehicles over time. Traditionally regulation has been fragmented with separate interventions covering safety, access to road networks, protection of road infrastructure, access to markets, and other factors. A more straightforward approach would be the tracking of automated freight vehicles and their performance across the network. Recent progress in mapping, sensor, and IT technologies makes such a solution feasible.

Consider government intervention to address labour issues if and where they arise

The automation of road freight vehicles could have a significant impact on demand for truck drivers. The extent to which reduced demand will increase unemployment among drivers is open to discussion, given continuing driver shortages. Depending on the magnitude of any impact on labour, government interventions may need to be considered. This could for example provide support for retraining displaced drivers. As the driver's role shifts away from purely driving to carrying out administrative tasks while on the truck, the driving profession could become more rewarding with automated road freight vehicles.

Automated road freight: An emerging challenge

The fast-evolving field of vehicle automation is a key development to the road freight sector. Vehicle automation is now a clear trend, with governments, Original Equipment Manufacturers (OEMs), and the IT sector competing for leadership in this space worldwide. A large variety of implementation scenarios in different sectors and environments are being developed. Due to the clear business case and comparably controlled environment, automation of road freight vehicles on motorways (ranging from twinning to platooning and full automation) has generated much interest. Traditional vehicle manufacturers as well as new players are entering the market with approaches such as retro-fitting of existing fleets, trucks with high-levels of on-board safety and driver assistance functionalities, and freight-matching platforms combined with fleets of fully-automated vehicles.

These developments, which may come about in the short- to medium-term future, will have a direct effect on all related legal and regulatory frameworks. There will be a large element of interaction between manually operated vehicles and automated vehicles (the level of automation can also vary amongst fleets and amongst the composition of vehicles using the road network simultaneously) in the transition period. In addition we might see the emergence of vehicle automation systems, which as a first step, still require a driver to be on-board at all times (with varying requirements to monitor vehicle performance and being able to take over control of the vehicle) or the use of control rooms staffed with operators able to regain manual control of vehicles if necessary.

A very data-rich space with high data connectivity is likely to emerge given both the specific implementation environment of vehicle automation for road freight, i.e. the whole motorway network, or specific high demand corridors, and the technical requirements for such operations... This is likely to enable the implementation of the novel data-driven regulatory approaches described above, based on all necessary data being directly collected and in principle being readily available through such a system (see earlier discussion on the potential need to mandate access to data vs. incentives for voluntary access). This will cover most, if not all, of the underlying policy objectives for market-based and vehicle-based rules. In addition, driver-based rules (e.g. driving hours, rest times, etc.) can also be covered, but here the requirements and the rationale behind the existing rules are likely to change based on the characteristics of such a scheme and the exact role and responsibilities of a driver or operator.

In the transition period we are likely to see solutions, where a driver will always, or on parts of the trip, be inside the cab. They will be able to immediately take control of the vehicle in a pre-defined time span and based on a hand-over protocol, gradually regain control of the vehicle either in case of system malfunction, or when entering parts of the network not equipped for full automation (e.g. part of the overall motorway network not equipped or leaving the motorway and going into more complex urban areas where full automation would be more difficult). In this case driver workload would be drastically reduced, allowing more flexible systems regarding working hours; this is also likely to be the key business case for logistics operators to invest in these new and likely more costly vehicles.

In the case of automation in conjunction with a control centre, regulations for working environment and working hours for these operators might have to be formulated. Furthermore, rules might have to be put in place to allow safe operation of manually operated and automated vehicles to interact in mixed-environment. In the, more long term scenario of full autonomy of vehicles without any drivers/ operators inside the vehicle or in a control centre, the category of driver-based rules would not apply anymore, but

this then requires a precise definition of roles and responsibilities of logistics companies, OEMs, and infrastructure owners or managers, in order to have a clear understanding of liability in case of incidents.

Various on-board safety systems for commercial vehicles have been developed and more innovative Intelligent Transport System (ITS) -based solutions are undergoing testing, including e.g. stability control, lane departure warning, driver drowsiness monitoring, etc. The need to identify, develop, test, and deploy innovative on-board technology solutions and practices are key areas of interest in this context.

Current research involves studying the collision avoidance effectiveness of wireless communication of safety information between heavy vehicles and light vehicles, cost effective after-market stability control systems for both tractor and trailer-only systems, identification of trailer characteristics from within the tractor in a cost-effective and reliable manner, and the development of driver management tools.

One potentially promising application area is vehicle automation for freight movements on motorways. This could allow highly reduced driver workload, more flexible working hours for drivers, and large safety improvements. Much work has been carried out specifically on this over the last ten years, with targeted near-market technology demonstrations being carried out.

Key research questions to be addressed going forward include:

- What specific technologies exist for the automation of Heavy Goods Vehicles (HGVs), covering different platooning (twinning or more vehicles) concepts and full automation?
- What are specific implications of the range of technology options on infrastructure requirements and human factors?
- In what way can such a system interact with both manually operated private transport and manually operated HGV not part of such a scheme?
- How can wider societal and economic benefits be locked in, without risking other additional negative effects e.g. “the wall of steel” at merging areas?
- How do these systems need to be regulated in order to allow safe operation and should this be driven by industry or should governments assist development?
- How does vehicle automation need to be regulated in order to allow safe operation and how are liability and privacy being addressed?

There is a general expectation with automated road vehicles generally, but particularly with (heavy) automated freight vehicles, that implementation of these technologies will lead to (immediate) large improvements of road safety. Work undertaken worldwide involving testing of vehicles and modelling of the likely implications of such vehicles suggest that reductions of accidents might be possible up to 80%. Some comparably large scale accident reductions can already be achieved at lower SAE automation levels, when on-board systems still have more of an assistance-functionality, including systems and technologies already available, such as lane departure warning systems (LDWS), or advanced emergency braking systems (AEBS).

The obvious reason for expected road safety improvements lies in increasingly keeping the driver (or more precisely the human element) out of the loop, which is currently often quoted as accounting for the vast majority of accidents. Much of the literature on this topic places it around 90%, although research into the human factors in transport and road safety points towards to this being a rather crude simplification. Nevertheless, a more (or less) gradual shift of driving tasks from the human driver to a control systems and the accompanying decrease in driver workload is very likely to have positive road safety implications.

Technology implications for truck automation

In Europe the so called “Truck Platooning Challenge” organised as parts of The Netherlands’ EU Presidency in 2016 provided a proof-of-concept of a relatively low-tech short-distance (also often referred to as a “virtual tow-bar”) following of a number of trucks behind a fully manually operated lead vehicle with a specific focus on the cross-border aspect. This culminated in the development of some guiding principles in this space (Declaration of Amsterdam, 2016).

In addition, the IRU Report “Commercial Vehicle of the Future” published shortly after this in early 2017, identified automation and platooning – amongst other ITS related trends - as key developments to have a very strong impact on how road freight transport and logistics operations will be organised in the future, also could contribute to a reduction in the sector’s environmental footprint. The report also states that the implementation of largescale truck platooning across the EU is a good example of political and legislative facilitation of new, compatible, EU-wide solutions, as well as interoperability between existing systems (Transport and Mobility Leuven and IRU, 2017).

It goes on to say that truck platooning will lead the way towards increased vehicle automation and then to the use of fully autonomous road freight vehicles. This will require a fundamentally different approach to the traditional rules on the use of the road, especially regarding the role of the professional driver. Fully autonomous commercial vehicles will undoubtedly provide new opportunities for vehicle and loading-unit design and substantially overhaul the way freight is moved by road and multimodal transport.

Further deployment of ITS will also speed up the digitalisation of road freight transport and logistics processes and the entire multimodal transport chain. The political and legislative groundwork that will allow further EU-wide progress needs to be carried out in advance. Wide-scale use of ITS and digitalisation will also create new opportunities for road freight transport and logistics operators to collaborate. The collaborative economy is introducing new ways of sharing resources and cooperating which could contribute to more efficient load factors. There will be a large element of interaction between manually-operated vehicles and automated vehicles. This interaction will occur with fleets and across the mix of vehicles on the road network, at least during a transitional period.

The need for near-term specific regulations

Much of the attention on vehicle automation technologies has focussed on issues relating to private passenger transport, such as urban congestion. At the same time, however, there is substantial evidence that long distance road freight tasks represent the most viable first application of advanced vehicle automation technologies, from technological, commercial and regulatory perspectives.

From a technological perspective, long distance road freight tasks are an attractive first application of advanced vehicle automation technologies. This because long distance road freight tasks make extensive

use of motorways. Motorways appear to be an easier environment in which to deploy more advanced vehicle automation technologies safely because they:

- tend to segregate the direction of traffic using dual carriageways
- use on and off ramps rather than intersections
- often have emergency stopping lanes
- often ban pedestrians, bicycles and animals
- tend to be better maintained than other roads with clear lane markings and well maintained pavements.

Also, extensive use of concessions, privatisation and tolling often give motorways sources of funding to maintain high quality standards more reliably than other roads. Together, these factors make motorways a less complex and, arguably, more predictable environment than other roads, despite involving higher speeds. They reduce the load vehicle automation technologies must be able to handle in order to operate a vehicle safely. In turn, this makes motorways a more viable candidate for the early deployment of more advanced vehicle automation technologies. As a large proportion of the long distance road freight industry's work takes place on motorways, it is arguably a good fit for vehicle automation technology.

From a commercial perspective, vehicle automation technologies represent opportunities to overcome current difficulties, improve productivity and reduce costs, which may lead to higher profitability. At lower levels of automation, the technological advancements assist human drivers and make driving heavy vehicles over long distances easier. At present, long distance freight tasks involve long periods of constant concentration on what can be a monotonous and, in turn, mentally draining task. It can also involve a heavy physical load arising from the need to control a heavy vehicle safely, especially when driving through adverse weather conditions such as strong cross winds.

These factors, amongst others, contribute to the difficulties carriers have attracting and retaining drivers. Comments from carriers in the United States and Europe indicate that these driver shortages are a stubborn and serious issue. However, technologies that are currently spreading through the market, such as adaptive cruise control and lane-keeping technology can relieve the human driver of some of the mental and physical load associated with driving a heavy vehicle over long distances. In turn, they may make these roles more attractive and contribute to alleviating driver shortage issues.

As vehicle automation technology matures, it presents further opportunities to operate vehicles more efficiently, saving on fuel and maintenance costs, delivering higher productivity and profits. At higher levels of automation, such as SAE levels 4 and 5, drivers become unnecessary, at least some of the time. At SAE level 4 a human driver is only required when a vehicle is outside its Operational Design Domain (ODD), while at SAE level 5 there is no human driver at all. Recent research indicates that human drivers currently represent between 35% to 50% of transport costs in European countries (Panteia, 2015, pp. 42-43). The serious negative labour impacts of higher levels of automation should not be understated. However, it is also true that higher levels of automation represent opportunities for carriers and consumers to obtain benefits from substantially lower costs. In turn, there are strong commercial incentives to deploy vehicle automation technologies for long distance road freight tasks.

From a regulatory perspective, major jurisdictions expect that motorways will be the first application of advanced vehicle automation technologies (G7, 2015), with road safety being the highest priority for vehicle automation technology across all uses. There is evidence that commercial road transport is already a relatively safe activity. Industry comments indicate that, of the collisions involving commercial

vehicles, most are not the fault of the commercial vehicle or its driver. Nonetheless, at least in the United States, driver error remains the leading cause of collisions, across all vehicle types (National Highway Traffic Safety Administration, 2015, p. 1). Improved vehicle automation technologies would assist human drivers and, ultimately, replace them. In turn, these technologies are hoped to eliminate many the collisions resulting from driver error.

Also, as computer processors have faster reaction times than human drivers, it is hoped that they will avoid a series of collisions that human drivers cannot. In turn, vehicle automation technologies are expected to significantly reduce fatalities and injuries, improving road safety (Cohen and Cavoli, 2017, p. 6). Long distance road freight tasks are an attractive first application of advanced vehicle automation technologies for regulators because of their limited use, in a more controlled environment (motorways) using professional drivers (at least at lower levels of automation). More so than through testing programs, this type of deployment allows regulators to obtain much better, real-world evidence in an environment that carries lower risks than urban roads. In turn, it allows them to design better informed, evidence-based regulatory frameworks and limit the negative consequences of any technological or regulatory failures.

While long distance road freight tasks are an attractive first application of vehicle automation technologies, there has been limited consideration of the regulatory issues that are particular to this operation scenario (Cavoli et al., 2017, p. 19). For example, in 2016 the National Highway Transport Safety Administration (NHTSA) released its Federal Automated Vehicles Policy. While the policy is applicable to all automated vehicles, industry representatives have expressed concern that it does not address issues specific to the automated trucks necessary to provide long distance road freight tasks and that the guidelines for these trucks are only expected in 2017 (Financial Times, 2017).

Consideration of regulatory issues specific to long distance road freight tasks would be beneficial. Effective regulation provides a foundation that benefits all vehicle automation stakeholders including developers, businesses, regulators and society as a whole. In this space, effective regulation would give freight carriers protection, giving them confidence that they can purchase vehicle automation technologies and use the services they provide safely, even if they have little knowledge about them. In turn, this provides a market for developers to sell into. Also, effective regulation provides certainty, reducing developers' investment risk and encouraging the innovation necessary to make vehicle automation a reality. Finally, effective regulation allows governments to influence how people behave in order to capture benefits and avoid negative consequences to society. Some freight carriers have advocated for regulation of vehicle automation technologies that are specific to the circumstances of trucks that undertake long-distance freight tasks (Financial Times, 2017).

The need for flexible and harmonised regulations

By their nature, long distance road freight tasks cross jurisdictions; both subnational jurisdictions within countries and international borders. As a result, long distance road freight tasks are susceptible to multiple regulatory frameworks applying to a single trip. In turn, diversity amongst regulatory requirements across jurisdictions has a greater impact on long distance road freight industry participants

than they do on individual passenger vehicle owners. For example, for the 2016 European Truck Platooning Challenge, regulatory requirements changed as the platoons crossed sub-national boundaries as well as national borders. To comply with them, participants had to comply with range of changing factors as they crossed jurisdictions, including (Dutch Ministry of Infrastructure and Environment, 2016, pp. 13-16, 21-22):

- maximum speed
- following distances
- types of motorway on which the platoon was allowed to operate
- the lane on the motorway in which the platoon was allowed to operate
- overtaking regulations
- the circumstances under which platoons were allowed to operate or required to decouple
- how to notify other road users of the presence of a platoon.

The example illustrates that it is possible for industry participants to invest in understanding diverse regulatory requirements and developing mechanisms to comply with them. It is also possible for drivers to operate vehicles differently and comply with different regulatory requirements in different jurisdictions. Therefore, while diverse regulatory requirements increase costs that are passed onto consumers, in many cases it is possible to comply with them. This may be an acceptable outcome, given that achieving uniformity may be impractical and a very slow process. For example, it can take many years to amend regulations promulgated by the Working Part 29 of the United National Economic Commission for Europe (UNECE) under the UNECE's Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions (the 1958 agreement).

As illustrated above, long distance road freight industry participants have a long history of complying with different regulatory frameworks applying to different parts of a single journey. However, that is not always possible. Vehicle automation software can be programmed to work with GPS equipment and operate a vehicle differently in different geographical areas. However, it is more difficult to change hardware as a vehicle crosses a border. As a result, having diverse regulations across jurisdictions could, at least, result in cross-border freight operators needing multiple on-board systems in vehicles, needing to change vehicles at jurisdictional borders or, at worst, effectively preventing certain vehicle automation technologies from being used in particular jurisdictions.

This is a particular risk because existing motor vehicle standards are detailed and prescriptive, and take long periods to change. For example, existing vehicle standards contain prescriptive requirements relating driver's seats, steering wheels and pedals. At higher levels of information, these regulations may impede a driver's ability to undertake productive work in addition to operating the vehicle or be inappropriate for completely driverless vehicles. As a result, while uniformity may not always be practical or desirable, more flexible, harmonised regulations are essential to ensuring that vehicle automation technologies can be deployed for long distance road freight tasks.

In the United States, this has been a particular issue. Several states have enacted legislation specific to automated vehicles. Many of those enacted to date have been focussed on testing, rather than operations and have similar elements, including:

- a definition of what constitutes an Automated vehicle (AV) and automated driving
- a requirement for AVs to abide by all existing road rules at all times
- developer responsibility for what occurs while the vehicle is in automated mode

An express legalisation of testing AVs on public roads, subject to conditions, such as:

- obtaining a permit to test an AV on public roads
- a requirement for a human driver to be present to take over manual operation at any time
- minimum insurance requirements
- obtaining further approval before commercial deployment.

However, some of them also have inconsistent licencing and other requirements (Norton Rose Fullbright, 2016), hindering the operation of these vehicles across state boundaries.

Developers and industry participants have been particularly concerned about harmonised regulation for vehicle automation technologies. They have advocated for these technologies to be regulated at the national and international levels. In the United States, Google, Lyft and Delfi have lobbied for the national safety regulator, NHTSA, to be the body responsible for regulating automated vehicles (Financial Times, 2016).

NHTSA has responded with a proposal for how to delineate regulatory responsibility between the United States' federal and state governments. It proposes States retain their traditional responsibilities (including licensing and registration, road rules, and insurance and liability regimes) (National Highway Traffic Safety Administration, 2016, p. 7) while NHTSA will continue its roles relating to uniform national standards for vehicle design. While imperfect, this somewhat reflects the split between those things that can and cannot be easily altered as a vehicle changes jurisdictions.

Other jurisdictions have also accepted the need for harmonised regulation in this space. For example, European Parliament documentation noted that European mobility requires a harmonised approach towards vehicle automation technologies, while fragmented regulatory approaches hinder implementation and jeopardise European competitiveness (European Parliamentary Research Service, 2016, p. 6). Similarly, the G7 Declaration on automated and connected driving notes that the full potential of autonomous vehicle technologies cannot be harnessed without a harmonised regulatory framework (G7, 2015).

Work on such harmonised regulatory frameworks is on-going. For example, the UNECE has commenced work to develop harmonised regulations for automated vehicle technologies. Similarly, the United States Congress is considering whether federal level legislation is necessary to ensure nationally consistent regulation for vehicle automation technologies. However, as is common, progress in regulatory harmonisation is being outpaced by technological advances. Without substantial movement in the near term, there is an increasing risk of a patchwork of different regulations for vehicle automation technologies, especially at the sub-national level.

Existing regulations cover short-term advances

While innovation is outpacing regulation in this field, existing regulatory frameworks contain mechanisms that are sufficiently robust and flexible to accommodate many of the vehicle automation technologies that are currently being introduced (or expected to enter operation in the near future) and the broader policy issues that arise from them. Only limited government action is necessary to facilitate these technologies. Vehicle automation technologies up to and including SAE level 2 are becoming increasingly common in commercial vehicles. Examples of these technologies include adaptive cruise control and lane keeping technology. Across major jurisdictions, there are extensive regulatory frameworks to promote vehicle safety and facilitate new technologies entering operation.

The United States, Japan and European Union all have extensive regulatory frameworks that set safety standards for new vehicles and components, and control how they can be brought to market. In the United States, the National Traffic and Motor Vehicle Safety Act 1966 regulate these issues. It empowers NHTSA to make Federal Motor Vehicle Safety Standards (FMVSS) and regulations to protect against unreasonable risk of crashes resulting from the design, construction, or performance of motor vehicles and unreasonable risk of death or injury should crashes occur (National Traffic and Motor Vehicle Safety Act (US), 1966).

As a result, NHTSA has set detailed, threshold requirements that all new vehicles and components must meet before being brought to market. Developers that wish to provide new vehicle automation technologies must self-certify that they consider those technologies meet the FMVSS before bringing them to market. Once on the market, NHTSA may purchase a vehicle containing the technology and use objective tests to determine whether it complies with the FMVSS.

Japan's Road Vehicles Act 1951 and the European Commission's Framework Directive on the type-approval of motor vehicles (Directive 2007/46/EC) use similar frameworks. Both of these frameworks have a focus on international harmonisation and ex-ante regulation. Like the United States, they apply detailed safety standards. However, unlike the United States, these standards are more likely to form their basis from regulations promulgated by the UNECE's Working Part 29 under the 1958 agreement. Both frameworks also include homologation rules providing mutual recognition of components and vehicles approved in other countries. Further, Japan and the European Union require developers that wish to sell new vehicle automation technologies to undergo testing and obtain approval from regulators before bringing the technologies to market.

Also, governments have mandating processes in place to update commercial vehicle safety technologies over time, such as the United States' and European Union's current phasing in of electronic log books. Some jurisdictions already have good regulatory practices, that determine what technologies to mandate and when to do so in a manner that does not "pick winners," and only mandates technology that regulatory impact analysis indicates has benefits that outweigh costs (OECD, 2009, p. 13).

The European Union has regulations that make this sort of regulatory impact analysis a regular process (Regulation EC 661/2009). Every three years the European Commission must provide the European Parliament with analysis of vehicle safety technologies. The analysis includes benefit cost ratios for mandating each technology considered and must include proposals for which technologies should be mandated (European Commission, 2015, pp. 10, 14). Having similar, regular reviews may promote the mandating of safety technology using a regular, more evidence-based foundation. In turn, it may

mitigate pressures and incentives that may arise from these issues being promoted on a political level using ad hoc legislative amendments.

There is evidence that the existing regulatory frameworks discussed above can effectively deal with many of the issues surrounding improvements to commercial vehicle automation technologies up to and including SAE level 2 that are likely to arise in the short-term. This is largely because the vehicle automation technologies relevant to long-distance freight tasks in the short-term assist drivers, without substituting for them. At this level, technologies such as adaptive cruise control may improve safety and productivity while reducing workplace health and issues by making it easier for the human driver to continue to actively control the vehicle at all times. The continuation of a human driver actively controlling the vehicle at all times enables many of the core structures and concepts in existing regulatory frameworks to continue to operate effectively.

For example, requirements around steering wheels, pedals and seat configurations remain relevant, as do concepts relating to “control” of a vehicle. Further, as regulation applies to human drivers, criminal penalties remain appropriate as tools that provide incentives for compliance. Also, many sub-national authorities that register/license vehicles to operate on public roads have broad powers to refuse to do so if they consider the vehicle to be unsafe (Walker-Smith, 2014, p. 495). Therefore, existing regulatory frameworks should be able to deal effectively with many aspects of these vehicle automation technologies, such as adaptive cruise control, that are becoming increasingly common in commercial vehicles.

This flexibility in existing motor vehicle safety standard frameworks may provide a period of breathing space for governments, in which existing regulatory frameworks can largely continue, while they prepare for more advanced vehicle automation technologies. Industry representatives, have called for regulators to use this period as a “homework phase” (Financial Times, 2017), in which regulators can better understand the regulation that more advanced vehicles automation technologies will need by funding research, skilling staff in AV issues or, as in the case of the United Kingdom’s Department for Transport’s Centre for Connected and Autonomous Vehicles, creating a specialist unit that can lead on AV issues across all of government. They can also use this period to focus on harmonisation efforts, rather than developing unique regulatory frameworks for vehicle automation technologies.

While existing regulatory frameworks are somewhat robust and flexible, there are some regulatory issues that remain to be addressed, even in relation to current technologies and their capabilities. For example, platooning has been highlighted as an activity, available using current technology, which can improve commercial vehicle fuel efficiency, reducing freight costs and carbon emissions. However, at present, there are regulatory impediments to platooning. These include:

- minimum safe following distances being too large to allow platooning
- an absence of rules regulating platoons such as how to inform other road users of the presence of a platoon and when a platoon should break up (for example, to protect bridge infrastructure)
- road rules relevant to platooning being set at the sub-national level but not clearly sign-posted, which impede voluntary compliance.

Each of these was evident as part of the 2016 European Truck Platooning Challenge where, to legally undertake the challenge, the six platooning teams travelling across five countries needed to obtain 19 exemptions with different conditions from varying national and sub-national authorities (Dutch Ministry of Infrastructure and Environment, 2016, pp. 20-21). Truck platoons are likely to deliver their greatest benefits in the trans-national and international freight arenas. As a result, there may be benefits to

further developing regulatory frameworks for truck platooning and ensuring that they are harmonised as much as possible.

Also, the effectiveness of some SAE level 2 technologies, such as automated lane keeping, depend on the ongoing maintenance of lane markings and other infrastructure to ensure that the technology can recognise them. This highlights that, while substantial infrastructure investment is often discussed as necessary to facilitate higher levels of vehicle automation (especially vehicle-to-infrastructure communication technology), less substantial investments to maintain motorway infrastructure at a high standard would also assist in facilitating the safety improvements that SAE level 2 technologies can provide.

Existing regulations are being stretched

In addition to being able to deal effectively with advances in vehicle automation technology that are expected in the near future, existing regulatory frameworks can be reinterpreted to deal imperfectly, but adequately, with some more advanced technologies. For example, a review of the United States' regulatory framework found that it would be sufficiently robust and flexible to accommodate technologies up to SAE level 4 (Volpe National Transportation Systems Center, 2016, pp. viii-ix).

This occurs because of how more advanced vehicle automation technologies operate and how relevant legislation is often drafted. SAE level 3 technologies, such as some highway pilot technologies, allow a vehicle to control itself for lengthy periods, with a human driver available to retake control when prompted. As a human driver is always present and available to control the vehicle, entire existing regulatory frameworks can apply to SAE level 3 technologies un-amended.

Similarly, many existing regulatory frameworks can stretch to cover SAE level 4 and 5 technologies. In many motor vehicle regulatory frameworks, concepts such as the “driver” and “control” of a motor vehicle are central. While these usually assume that a human driver will control the vehicle, sometimes assumption is implicit, not explicit. This creates room for expansive interpretations. For example, while it was originally designed with a human in mind, the term “driver” could include multiple drivers or operating software (Walker-Smith, 2014, p. 463).

There are several advantages to this approach. It is consistent with industry views that prefer adapting existing frameworks over creating new frameworks that may lock in a standard that is too high or too low (Corporate Partnership Board, 2015, p. 6 and 27). It is a relatively easy mechanism by which to ensure that automated vehicles conform to the same norms as human driven vehicles that currently dominate on the road, especially in relation to road rules. It also reflects the history of transport regulation. When automobiles first appeared on public roads, they were required to comply with norms applying to the then dominant transport mode - horses. Also, regulatory reform can be slow. Interpreting existing regulatory frameworks expansively can avoid holding back more advanced AV technologies.

Stretching regulation creates challenges

While interpreting existing regulatory frameworks expansively has advantages, it also presents challenges. Stretching existing regulatory frameworks can be a relatively blunt mechanism. It can deliver unintended consequences such as unnecessary impediments to innovation or allowing the premature deployment of technologies. Issues relating to the deployment of SAE level 3 technologies to assist in long distance road freight tasks illustrate these points. Automated vehicles that can operate on a broad range of public roads without a human driver are still years away (Isaac, 2016, pp. 12-13; Shladover, 2017, p. 7). Ford intends to have high-volume, SAE level 4 automation-capable vehicles in commercial operation by 2021 (Ford, 2016). However, as SAE level 4 vehicles; these are likely to be limited to a specific and narrow operational design domain (ODD).

They are unlikely to be able to operate in automated mode beyond some combination of low speed, relatively small geographical areas, less complex environments, segregated lanes, specific weather and road conditions and times of day. Such vehicles are unlikely to be able to operate comprehensively in the dense urban environments (Cohen and Cavoli, 2017, p. 14), where the opportunities for safe, more accessible and less congested transport that AVs promise are most desired. For that, technology that allows automated vehicles to have wide ODDs would be necessary. Using the most optimistic estimates, we are still decades away from that technology (Isaac, 2016 p. 13). Some estimates suggest that we will not see such vehicle automation technologies until around 2075, if ever (Shladover 2017, p. 7). SAE level 3 technologies are much closer. However, evidence relating to safety is still unclear.

Amongst freight carriers (Financial Times, 2017) and developers (Davies, 2015), there is support for the deployment of SAE level 3 technologies, such as some highway pilot technologies. These technologies offer benefits to commercial vehicle drivers and the carriers they work for. Some industry participants (Daimler, 2015) hold the view that drivers of vehicles equipped with SAE level 3 technologies can be more attentive (as measured by Electroencephalograms (EEGs) and, electrocardiograms (ECGs)) and are consequently able to perform better, if the technology allows them to also do other jobs instead of having to perform monotonous driving-related tasks. Their research indicated that drowsiness fell by 25% when the truck operated in autonomous mode and the driver performed interesting secondary tasks (e.g. on a tablet computer). Similarly, there is some industry evidence from the passenger vehicle sector indicating that, on some measures, vehicles using SAE level 3 technology may have lower fatalities than those using less advanced or no automation technology (Musk, 2016).

If correct, the information above may indicate that not needing to exercise active control over a commercial vehicle at all times may reduce the physical load on commercial vehicle drivers, make their roles more interesting and provide them with opportunities to increase productivity. In turn, this may increase safety while making their roles more attractive, assisting to further improve commercial vehicle safety and mitigate the current driver shortages and high turnover that seem chronic in Europe and North America.

For carriers, these benefits might also provide evidence to support seeking more flexible hours of work requirements (Davies, 2015), increasing profitability. However, the evidence in this area is disputed and more study is necessary to better understand the impacts of SAE level 3 technologies. While these may bring benefits to the commercial vehicle industry, they also carry risks. SAE level 3 is arguably the most controversial level of automation because of the limitations of human drivers, rather than the technology itself.

SAE level 3 technology allows a driver not to concentrate on the driving task, so long as they are available to regain manual control of the vehicle at any time. Industry and academic research in the private passenger vehicle space are raising questions as to whether it is feasible for this kind of handover from vehicle to human driver to occur safely. In a motorway experiment of non-critical handover (Merat and de Waard, 2014), 35-40 seconds were required for a distracted human driver to achieve stabilised lateral control of the vehicle.

This was irrespective of whether handover from the AV had been planned or was in response to a critical event. At motorway speeds (such as 70 miles per hour or 110 kilometres per hour), during a 35-40 second handover, a commercial vehicle would have travelled more than 1 kilometre. There is also evidence from academic research (Jamson et al., 2014) that drivers in an automated condition showed 2% higher drowsiness than in manual conditions. There is also some evidence from industry to support this view (Bloomberg Technology, 2017).

Evidence of difficulties relating to handover largely arises from the passenger vehicle sector, rather than the commercial vehicle sector. It is not entirely clear how professional drivers with appropriate training would respond to a handover situation that requires them to leave secondary duties and regain manual control of a vehicle. Handover may be safer with a professional driver, similar to how autopilot technologies work on aircraft. However, it is not clear that the reaction times of distracted professional drivers would be substantially different from those of other drivers.

Also, the need to be available for handover may limit the non-driving activities a driver can undertake, reducing productivity. In turn, there are questions about the technical and commercial feasibility of SAE level 3 technologies. These concerns have prompted a divergence in approaches to SAE level 3 technologies, with some developers focusing their efforts in that space and others deciding to skip over SAE level 3 technologies, focussing on SAE level 4 technologies.

For regulators, these types of concerns have led to a discussion around whether it should be legal for vehicles to operate at SAE level 3 (Bloomberg Technology, 2017) and, if so, what regulatory changes are necessary to ensure they do so safely. However, because vehicles with SAE level 3 technologies continue to require the constant presence of a human driver, existing regulatory frameworks can be stretched to make them legal in many jurisdictions (Volpe National Transportation Systems Center, 2016).

For example, the Freightliner Inspiration has already been licensed to operate Nevada in the United States. As a result, pro-active government action would seem necessary in several jurisdictions, if regulators considered that SAE level 3 technologies were not yet sufficiently safe to be deployed.

Similar issues also arise at higher levels of automation. On 20 October 2016, Otto (an automated truck developer) made the first commercial automated truck delivery, shipping a product across Colorado in the United States as a one-time demonstration, using a truck equipped with SAE level 4 technologies. Colorado's laws and regulations do not expressly authorise or prohibit the operation of AVs, as they do not address the scenario at all. As a result local authorities felt they were not empowered to prevent Otto from operating in their jurisdiction, had they wished to. Instead, they worked with Otto to develop a framework to ensure the delivery took place safely (Savage, 2017).

This included Otto initially testing its automated truck off public roads, providing Colorado regulators with contingency plans and off road test data, certifying the safety of the vehicle, demonstrating appropriate insurance and successfully completing five successive test drives without human intervention (but with continuous human monitoring and supervision). In addition, Colorado regulators inspected the vehicle and conducted a company safety audit of Otto. By working together, Colorado and

Otto were able to successfully develop protocols that satisfied all stakeholders. However, flexibility in existing regulatory frameworks required them to do so from a less favourable starting position.

These examples illustrate that there are advantages and challenges that come with stretching regulatory frameworks to cover more advanced vehicle automation technology. The advantages tend to accrue in the short term, while the challenges mount as time progresses. Ultimately, as vehicle automation technologies enter deployment, policy makers and regulators will need to revisit motor vehicle regulatory frameworks and either fully adapt existing frameworks or develop a single regulatory framework that applies well to both automated vehicles and those with human drivers or a separate regulatory framework for automated vehicles. In particular, it seems likely that road rules will need to change to reflect the capabilities of vehicle automation technologies.

Use of innovative data-led regulatory approaches

The emergence of big data and its application to the transport sector has enabled various innovative solutions and business models, but uptake in the area of road freight transport has been somewhat slower compared to other domains. This new context of a richer and more timely availability of data should make it possible to develop smarter, evidence-based policies and more flexible data-driven legislation and regulations, and with it the potential to deeply change how the road freight sector operates and is regulated, bringing large scale improvements to both supply chain efficiency and transparency and responsibility of the sector.

The application of such approaches to the regulation of fully automated (i.e. SAE level 5) vehicles holds the promise of providing a framework for governance once the traditional regulatory framework has reached “breaking point”. In addition, such a comprehensive approach for regulating the use of automated vehicles for road freight transport might be able to integrate all aspects, i.e. also those beyond the type approval of ensuring safe operation of vehicles. Much of the underlying information required for regulating the various aspects of road-based freight transport relates to the geo-location of vehicles over time.

Different techniques have traditionally been used to gain the necessary insights to see at least parts of the overall picture, thus supplying sufficient information for regulators to monitor adherence to regulations put in place. A more straightforward approach, seeing the whole picture through one stand-alone system, disposing of the individual fragmented systems currently used, would be tracking of automated freight vehicles in the network. Recent progress in mapping, sensor, and IT technology has enabled the implementation these technologies and solutions.

In road freight transport rules can be classified in one of the following three groups:

1. Market-based rules: apply to road haulage operators and regulate their access to the road transport market or its specific segments; they could be rather general and specify what provisions the haulier has to fulfil to obtain a licence and be able to operate in the market, or specific, e.g. defining the requirements for transporting dangerous cargo in a specific location of the road network.

2. Driver-based rules: apply to the access to the profession and the actions of the driver when at work, resting or in the state of availability to perform their duties; they include social rules, but also relate to actions that the driver might take when driving, including those regulated by the traffic code.
3. Vehicle condition rules: relate to the technical condition that the vehicle must meet to be able to perform freight transport operations in the market.

In terms of the technical solutions implemented, there is likely to be a large element of interaction between manually operated vehicles and automated vehicles in the transition period. The level of automation can also vary amongst fleets and amongst the composition of vehicles using the road network simultaneously. In addition we might see the emergence of vehicle automation systems, which as a first step, still require a driver to be on-board at all times or the use of control rooms staffed with operators able to regain manual control of vehicles if necessary.

High automation levels and labour market issues

As mentioned earlier, there are strong commercial incentives for long distance road freight carriers to pursue higher levels of automation. Within Europe there is evidence that labour costs currently account for 35%-45% of the operating costs of road freight (Panteia, 2015, pp. 42-43). In many jurisdictions, there are restrictions limiting the hours a driver can drive on a given day or during week. Also, in some jurisdictions, there are limitations on the types of trips that can be conducted by a foreign driver (such as cabotage limitations) to protect the dignified conditions of local drivers.

Simultaneously, there are driver shortages, especially for long distance freight tasks. Together, these factors can limit the speed and reach of long distance road freight, increase costs, reduce productivity and, in turn, reduce profitability. In addition to safety, fuel efficiency, asset utilisation and environmental performance benefits, by reducing and eventually removing the role of drivers, vehicle automation technologies present the possibility of substantial cost reductions to freight carriers and their customers. As a result, absent government intervention, it seems likely that there would be substantial and potentially rapid take up of autonomous vehicle technology to undertake long distance road freight tasks.

The study, *Managing the transition to driverless road freight transport* (ITF, 2017), uses evidence relating to the take up of disruptive technologies in the past and industry expertise to develop four scenarios for how advanced vehicle automation technologies could impact labour markets in Europe and North America. The study concluded that substantial labour impacts were likely to arise as a result of the introduction of advanced vehicle automation technologies and proposed potential government interventions (supported by project stakeholders), which affect the speed of introduction of advanced vehicle technologies and ensure adequate support to displaced drivers.

Potential government interventions affecting the speed of introduction of AV technologies according to this study included the following:

- establishing a temporary transition advisory board to advise governments on these strategies

- introducing a permit system to influence the speed of introduction of advanced autonomous vehicle technologies and the associated job losses
- economy wide support for underemployed individuals, such as universal income policies
- industry specific support for displaced drivers, consistent with good practice for general unemployment support, funded by the main beneficiaries of the technologies.

On the other hand, the roles of drivers that remain would likely be less focussed purely on driving, with the potential for more “back office” tasks to be undertaken in the cabin. This could help make the truck driving profession more appealing than the existing roles.

Whilst there was agreement on these changes to the roles of truck drivers with the advent of vehicle automation, discussions at the roundtable disputed the magnitude of the labour market effects. This view was mainly based on the fact that there is an increasing truck driver shortage in many markets (particularly North America) and on doubts over the speed of technology implementation. Intervention was therefore not viewed as necessary.

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Commercial Vehicle On-Board Safety Systems

This report analyses the impacts of increased automation of the driving task for road freight transport. It investigates the technology options from platooning to full autonomy and examines necessary policy responses. Focusing on the underlying regulatory frameworks, it asks how existing approaches can be maintained and when and how novel solutions will be needed.

All resources from the Roundtable on Commercial Vehicle On-Board Safety Systems are available at:

www.itf-oecd.org/commercial-vehicle-safety-systems-roundtable

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