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A barrier to innovation:
Europe's ad-hoc cross-border framework for testing prototype autonomous vehicles

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ABSTRACT

The conglomeration of regulatory frameworks for the testing of prototype autonomous vehicles in Europe creates a challenging task for developers and researchers planning pilots across borders. While there are examples of international autonomous driving projects and cooperation in autonomous vehicle research, Europe lacks a mutually recognised testing procedure for autonomous vehicle pilots, and incompatible legal and administrative processes in each country creates a disincentive for ambitious cross-border testing. The diverse climate and topography of Europe potentially provides a rigorous testing ground for autonomous vehicles, and an opportunity to prepare the new technology to deal with varied signage, language and driver behaviour encountered when travelling across multiple countries. Prototype vehicles tested in such conditions provide valuable insight for research and product development. This may be encouraged by a more harmonised prototype testing framework including a pan-European type-approval exemption scheme for prototype vehicles, and for cross-border tests to be coordinated by regional organisations interested in promoting development in border areas.

Keywords: Autonomous vehicles; cross-border testing; regulatory sandbox; Euroregion

1. Introduction

The development of autonomous driving technology has been linked to benefits at the individual level by potentially increasing access to transport for those unable to drive (Harper et al. 2016), and permitting alternate time use during travel (Steck et al. 2018). At the societal level potential benefits projected include economic development though improved transport links (Fontes et al. 2014) , and a reduction in the number of road traffic accidents, injuries and deaths currently caused by human driving error (Kalra 2017). In order to develop autonomous technologies and to ensure reliability and safety, prototypes of autonomous vehicles are tested on public roads encountering the normal rigours of travel, while interacting with other road

users. Although virtual and simulated testing, accelerated testing[1] (Zhao et al. 2017) and mathematical modelling (Hojjati-Emami et al. 2012) form part of the strategy to improve technology (Kalra 2016), such research is built upon on real-world testing. The exposure of autonomous vehicle technology to realistic conditions remains vital to ensure these vehicles live up to the expectation that they will improve journeys by road.

At a national and international level, regulation is being developed along-side technology in preparation for the deployment of highly autonomous vehicles[2] (SAE 2018) on public roads. Vehicle functions which are capable of continuously determining manoeuvres without driver command[3] (UN Regulation 79, 2018) are not available for type-approval (EC Type Approval n.d.)[4] under existing European uniform safety and technical provisions. Type-approval, or an exemption from type-approval, is required for all driving functions included within a vehicle, before manufactures may release a new model onto the market. However regulations which contemplate highly autonomous vehicle functions are being refined in preparation for commercial deployment of such models[5] (UN Regulation 79, 2018). The European Commission has confirmed a strategy for permitting a harmonised exemption procedure to type-approval for autonomous vehicles, however this is limited to commercial series production vehicles, and does not apply to prototypes (EC Exemption Procedure 2019). In many European countries, prototype autonomous vehicles cannot be driven on public roads without authorisation from a local authority. Consequently, while harmonised regulatory developments for highly autonomous vehicles are being prioritised to prepare for commercial deployment in Europe, the same cannot be said for research vehicles. The administrative and legal framework for cross-border testing of prototype autonomous vehicles in Europe is significantly under-developed. The treatment of cross-border testing at the pre-deployment and research level is determined by the national frameworks of each European country, featuring both misalignment, and duplication. These difficulties have been identified via internationally coordinated research involving highly and partially automated vehicles, such as

[1] Accelerated testing involves subjecting the vehicle to conditions beyond its normal parameters to uncover faults in a shorter timeframe

[2] Highly autonomous vehicles in this article refers to vehicles which fall within SAE J3016 Level 3-5. Such vehicles are partially or fully self-driving vehicles, where a driver is not actively engaged in the driving task for at least part of the journey

[3] Otherwise known as 'ACSF of Category E'

[4] Type-approval of vehicles in Europe refers to the national process to certify a vehicle meets all EU safety and environmental requirements

[5] An example of this is the uniform provisions regarding steering equipment

the recent AUTOPILOT[6] project, and the European Truck Platooning Challenge (Government of the Netherlands 2017)[7] which involved negotiating the different legal and administrative requirements for testing autonomous vehicles on public roads throughout Europe. Over multiple jurisdictions across Europe, these projects applied for permission to execute pilots citing specific routes, infrastructure, and the vehicles required type-approval exemptions where they were modified to include highly autonomous functions. Applications were made not only to each country involved but often permission was sought from each local government and road authority. In cross-border research, the responsibility of coordinating the required permissions between each country rests with the research body or developer. In the face of such difficulties, the future deployment of autonomous vehicles by European developers may be inhibited, delaying the potential benefits associated with their widespread delivery. The following explores the importance of cross-border testing, and considers the national testing processes of the Netherlands, Germany and Austria as case study examples demonstrating the diverse procedures across Europe, before exploring alternative regimes which may address some difficulties associated with pre-deployment testing.

2.The potential of autonomous cross-border transport

Cross-border road and transport activities constitute an essential component of Europe's economic strategy while providing quality of life and opportunities for its citizens. Cohesive transport networks are required for the smooth operation of the internal market, mobility of people, goods and the economic, social and territorial cohesion of the EU (Fontes 2014). Any lack of political and administrative coordination, in addition to restrictive national law and policy may hinder the formation of efficient cross-border initiatives (Cavallaro 2019). As recognised in the Declaration of Amsterdam,[8] any efficiencies or benefits, such as improved safety which could be offered by autonomous vehicles[9] (Kalra 2017) could potentially have a positive impact for 1.7 million commuters crossing national borders |(EC, Cross Border 2015),

[6] AUTOPILOT concerned research into the how the internet of things may be used to develop autonomous vehicles and involved pilots across Europe and South Korea. Such research will be discussed further below.
[7] The 2016 ETPC investigated the efficiencies which could be derived from European transport links utilising semi-autonomous platoons of trucks, and will be discussed further below
[8] In 2016 the EU Member States signed the Declaration of Amsterdam on self driving and connected vehicles to declare cooperation in the pursuit of connected and automated driving, to strengthen the economy, improve mobility in rural cities, contribute to decarbonisation of transport, and benefit an aging population and vulnerable road users
[9] For example, a study by RAND corporation, which compared the potential number of lives saved from automobile accidents under "Improve10", "Improve75" and "Improve90" strategies, proffers that if we are able to deploy safer vehicles cars sooner, which are only 10% safer, they will save more lives overall than waiting to deploy technology until the cars are 90% safer

and the one-third of the population living in border regions (Cavallaro 2019). Labour market mobility is of particular importance to border regions, and it is part of every-day life of citizens to cross the border to access work or leisure (AEBR 2012). One of the most persistent barriers to mobility within the EU for citizens, commuters and tourists, relates to problems with cross-border transport (Medeiros 2019). Road transport remains the dominant mode of transport in Europe, with 70% of all transport being delivered by road and one-third being cross-border (EC, On the Move 2017). A well-functioning transport system connecting the EU and neighbouring countries is crucial for sustainable economic growth and the wellbeing of EU citizens. Better integration of national networks will contribute to fostering cooperation and integration between the EU and its neighbouring countries (Medeiros 2019). European autonomous vehicle projects which incorporate cross-border research could inform the strategy to develop the European economic region.

3. European Diversity

Europe provides a platform for diversified autonomous vehicle research, exposing new technology to a variety of geography, climate, language, law, driving customs, population density and infrastructure. Data and analysis stemming from pilots undergoing the rigours of such varied parameters, is valuable to ensure that developing autonomous vehicles are safe and fit for the purpose of commuting and providing transport links in Europe.

Centuries of nation-building across Europe has led to physical borders serving to segment markets and demarcate political and legal jurisdictions (Roderick 2000). The distinct history of each country has played a part in how the law and regulatory frameworks have been developed. A road journey across multiple countries in Europe may encounter obstacles that persist even in a context of free movement inside the European Union, which has 38 internal land border regions (Christodoulou 2018). European countries feature different languages, road signage markings and rules relevant to prototype testing. Perception functionalities of autonomous systems, including recognition and behaviour adaptation when encountering road signage, traffic signals and road markings, is essential for any prototype which is proposed for cross-border use including commuting and goods transport (Government of Luxembourg 2018). While most road signs in Europe are standardised under the 1968 Vienna Convention on Road Signs and Signals (UNECE 1968), some national road signs are relevant to the geography and features of the local environment and do not appear in every European Country. Pedestrian

crossing lights for example, vary throughout Europe (Gödeske 2011).[10] Vehicles in England drive on the opposite side of the road to France, relevant because these countries are connected by the 50km Channel Tunnel, whereupon commuters and freight links must drive on the opposite side of the road from the country in which they began their journey, currently only a hypothetical challenge for autonomous vehicles. Protocols to ensure a vehicle does not emerge from the Channel Tunnel on the wrong side of the road must be developed and tested (Pearah 2017). Autonomous vehicles crossing borders must comply with local traffic laws which are far more obscure than which side of the road to drive on. Laws from country to country differ, and in some instances, laws involve open concepts such as forbidding the driver to 'cause danger', 'impede traffic', 'make an unnecessary noise' or guidelines which instruct drivers to keep right 'as much as possible'(Prakken 2017). The adaption of autonomous vehicles to such changes in a single pilot would provide evidence the technology is up to the task of driving safely on European public roads as part of a normal journey. Whether laws should be adapted to incorporate autonomous vehicles, or whether the new vehicles can adapt to the law, is a decision that would be better informed by cross-border prototype testing. As well as formal road signage, driving requires traversing a range of social and unspoken signals (The Conversation 2018),[11] such as another driver flashing a vehicle's high beams, the meaning of which is highly dependent on the context and the place. Differences in unspoken and unwritten signals arguably magnify when a vehicle travels though multiple countries.

The differing geography and climate of European countries is also relevant to the impact on autonomous vehicle performance. European roads are scenes of varied weather and conditions potentially affecting vehicle functioning such as; snow, ice, fog, elevation, heatwaves and softened asphalt. A key shortcoming in autonomous vehicle research is all-weather testing (Radecki 2016). Even where temperatures and weather patterns are less extreme than these examples, the recognition and adaptation of behaviour to adverse weather conditions is necessary for the long-term planning of autonomous vehicles in Europe.[12] Environmental perception is a cornerstone of prototype testing (Armingol et al. 2018). Arguably, autonomous vehicle testing would benefit from pilots taking place across multiple regions, to ensure

[10] Such as the Ampelmännchen "little traffic light men" originating in East Germany
[11] In this article the author describes the maneuverer of the 'Pittsburgh left' a car immediately turning left on a green signal narrowly avoiding the oncoming traffic
[12]Bundesministerium für Verkehr and digitale Infrastrktur (Germany) 'Franco-German – Luxemburgish cooperation on automated and connected driving, Concept for the Cross-Border Digital Test Bed'

vehicles can handle a full range of weather and other conditions[13] (Stock 2018). Such diverse testing is currently taking place in the USA with pilots at Lake Tahoe during snowfall, and Death Valley California, one of the hottest places on Earth (Medium 2017). It is reasonable to argue that the developers and researchers which have access to diverse climate and geography on which to conduct their real life testing, and on which to base their simulated, accelerated and mathematical modelling, would be at an advantage.

The safe development of technology depends upon the collection and analysis of potentially valuable data relating to operation of new technology in varied terrain and weather, region-specific infrastructure, laws and driving conventions.

4. National Regimes

Each European country applies a different legal framework to autonomous vehicle testing. This varies from countries which have little nor no formal processes,[14] to countries which support a self-certifying framework (Centre for Connected and Autonomous Vehicles 2019),[15] to those which operate a prescriptive procedure requiring explicit permission for testing to occur on roads within its borders. [16] The safety of the public and test participants stands at the heart of any national testing framework or code of practice. In countries which operate a prescriptive procedure, there are typically two requirements for autonomous vehicle testing. Firstly, the vehicle itself must be approved, and secondly, the location and design of the test must be risk-assessed. As there is no European type-approval (EC Type Approval, n.d.) for highly autonomous vehicle functions, prescriptive authorities provide exemptions for autonomous prototypes operating in their jurisdiction if the authority is satisfied that the experimental function complies with their requisite safety parameters. Secondly, the proposed pilot, route, use case and the infrastructure required must be considered following risk analysis procedures or a code of practice developed by the relevant authority or state, if there is one. Further, the regional authorities responsible for infrastructure must be consulted. While European countries do share testing facilities, there are no true autonomous vehicle testing

[13] In the US testing by Nutonomy, snow and seagulls emerged as serious challenges US can test in different weathers and terrain

[14] Cyprus does not yet have any formal framework for the testing of prototype vehicles

[15] The UK permits autonomous vehicle testing whereby the test organisers are responsible for complying with all traffic and road laws, and has established a Code of Practice regarding such tests

[16] For example, countries such as the Netherlands and Germany operate a prescriptive, permission-based approach to autonomous vehicle testing

corridors, there are only infrastructure and connectivity testing corridors. This is because there is no mutually recognised testing permit procedure in place between any European Country.

Far from signalling the end of European borders, the EU has been instrumental in promoting territorial integration within the EU (Medeiros 2019). To some extent, the complex interplay between national sovereignty and territorial co-operation inhibits the implementation of formal spatial planning visions that support a strategic implementation of international projects (Braunerhielm et al. 2018). Many European countries have individually declared their intention to become a 'leader' in the field of autonomous vehicle testing and deployment, and as part of that aim have produced their own application and testing process. These administrations are highly dependent upon further procedures embedded within their regional frameworks, as demonstrated in the processes used in the Netherlands, Germany and Austria.

Considering examples at the national level, the Netherlands operates a prescriptive exemption process, with a national vehicle authority, the Rijks Dienst Wegverkeer ('RDW') dealing with all prototype exemptions and autonomous vehicle tests. The regime governed by the RDW places safety as a paramount concern, recognising risks which may be introduced by allowing autonomous vehicles on public roads (RDW 2017). The Dutch approach to managing risk is to provide explicit parameters regarding the condition of the vehicle, the location of the testing and how it may be carried out[17] (Vallinga 2017). RDW exemptions and test permissions, take into account any number of the 225 provincial and municipal authorities in the Netherlands, with the RDW negotiating with the relevant authority on the applicant's behalf as part of the exemption process. Each authority may refuse to participate in a proposed autonomous vehicle test, and it is only once the relevant authority agrees that the exemption process operated by the RDW applies.[18] Exemptions provided by the RDW are not mutually recognised in any other country. However the RDW has stated it may recognise an exemption from other jurisdiction. Such mutual recognition is highly contingent on the individual case and the quality of the supporting evidence (RDW 2017).

[17] The advantages of binding regulation and the exemption process operated by NL includes that the safety and standards relevant to AV are closely monitored by government, and violations as such standards may be linked to sanctions and administrative or criminal interventions already built into the framework.

[18] The test cannot proceed unless the RDW has carried out physical tests of the vehicle including on a test track, and stress test where the vehicle is tested in less than ideal conditions, and the relevant road authority has given permission: RDW (2017)

In Austria, applications for the testing of autonomous vehicles are received on a national level by the Federal Ministry of Transport, Innovation and Technology. Applications are considered quarterly from a technical and legal standpoint (Austriatech, Test Applications, n.d.) under the Ordinance on Automated Driving (Federal Ministry Republic of Austria, Autonomous Driving) However in order to perform tests on public roads in Austria, the relevant provincial government must be informed about the tests including which roads will be affected, and where the test involves infrastructure such as traffic lights and roundabouts, the relevant local authorities must be contacted and permission received. Municipalities are responsible for administration related to local traffic areas and must be consulted regarding test proposals (Republic of Austria, Constitution). This is despite any national testing agreements in place with other countries. For example, Austria, Hungary and Slovenia signed an agreement in March 2018 on cross-border testing as part of an action plan on automated mobility, accompanied by an alliance between test infrastructures and road operators (Federal Ministry Republic of Austria, Action on Mobility). However, the agreement does not introduce mutually recognised exemptions for vehicles which do not comply with type-approval, nor does it cover approval for pilots. Test permissions are still required as per national and regional requirements, there is no reciprocal legal recognition as part of the international agreement.

In Germany, the testing and certifying process as it exists from state to state is not transparent. Autonomous vehicle prototype test certification is performed by each regional government, and test authorisations are normally assigned to original equipment manufacturers ('OEMs').[19] The automotive industry is prominent in Germany employing nearly 800,000 people and producing 70% of all premium brand vehicles. It is these OEMs which typically undertake local and long-distance tests throughout Germany (Ttnews.com 2019). While federally the relevant national body is the Federal Motor Transport Authority, each regional government must be consulted about autonomous vehicle testing, and each has its own individual requirements. There are plans to streamline this permission process within Germany via a process known as 'Bundes-Länderanfrage'. Once permission is obtained from one regional government the permission may be extended. However this would only apply to German states (Arrúe et al. 2018). It is possible that smaller countries may accept a test certificate originating from Germany, however this is unlikely to occur the other way round.

[19] German automotive OEMs include; Audi, BMW, Porsche, Mercedes and Volkswagen

On a practical level, to assist international developers, national application processes across Europe for pre-deployment testing are often published in languages other than the national language. However, some of the procedures relate and refer directly to national legislation which may not be readily available in the developer's language. In order to fully comprehend the parameters of the process, it is necessary for international applicants to understand the regulatory framework underpinning the process, particularly where they may wish to challenge the process or make an application which approaches the very limits of what is permissible in that member state. Consequently national procedures may also inhibit testing applications due to the processes being governed by national law which is not readily translated or understood.

On the whole, individual countries managing the minimum technical requirements for automated technology produces duplication and potential delay for cross-border testing (International Federation of Accountants and Business at OECD 2018). In some cases the variations in application processes merely set out different ways of achieving the same outcomes (Bomley 2017). This was encountered in cooperative cross-border pilots such as AUTOPILOT and the European Truck Platooning Challenge.

5. International Cross-Border Research

The Horizon 2020 AUTOPILOT project investigated the role of the internet of things[20] in the development of autonomous vehicles, and entailed the cooperation of 45 organisations across Europe to execute tests on 6 pilot sites, 5 of which were trials conducted in separate European countries (AUTOPILOT 2019).[21] The research investigated aspects of vehicular behaviour adaptation, including how the safety of autonomous vehicles may be increased by utilising cellular and internet enabled devices to detect and avoid vulnerable road users. The complexities presented by cross-border legal issues were circumvented in AUTOPILOT, as tests were constrained in an area governed by one regional authority. Restricting a test to one region reduces the time and the number of legal permissions to obtain. Internationally developed vehicles were able to participate in AUTOPILOT without seeking multiple permissions by being transported across Europe by vehicle-carrier to test sites.[22] Consequently,

[20] The internet of things is used to describe devices such as mobile phones which are able to send and receive data for example see: Burgess 2017

[21] The European sites were; Tampere, Finland, Versailles, France, Livorno, Italy, Brainport, the Netherlands and Vigo Spain. The project also included tests in Daejeon, Korea

[22] For example in the AUTOPILOT project, the French based partner, Valeo, and the vehicle supplied by the German Aerospace Centre (DLR) transported prototype vehicles from their respective countries to the testing site in Brainport, Netherlands by vehicle carrier.

collaborative testing took place on sites encapsulated in one jurisdiction, with multiple partners contributing from various European counties. However none of the AUTOPILOT tests involved an autonomous vehicle crossing jurisdictional borders. There are examples of pilots which have included cross-border testing as part of the research methodology, such as the European Truck Platooning Challenge.[23]

The European Truck Platooning Challenge involved fleets of partially autonomous trucks driving in a convoy formation across the borders of 5 European countries. Technology-assisted truck platooning is researched to create efficient transport systems in order to reduce problems such as emissions and congestion (Davila 2013). The project sought insight regarding how trucks fitted with vehicle to (Tobar et al. 2019). However the administrative and legal processes for conducting such pilots was significant. The European Truck Platooning Challenge provided a knowledge base regarding the varied exemption or test application procedures in Sweden, Denmark, Germany, Belgium and the Netherlands. From a legal perspective, the project investigated the procedures adopted by each of the relevant authorities, including the local application procedure, the information required by each body and how each authority assessed vehicle functioning. This information was gathered on each country, with two separate applications taking place for Germany; Southern Germany (Bavaria and Beden-Württemberg) and Northern Germany (Schelswig-Holstein). The existing national requirements for the approval of prototype vehicles required in total, 19 exemptions, and required applications to be made to 8 road authorities. The permits obtained to perform the platooning project from country to country regarding the safe travelling distance between trucks ranged from 0.5 seconds at 90km/h to 1.3 seconds at 80km/h. Within Germany the permits ranged from 0.5 seconds at 80km/h in Baden Württemberg to a 1 second gap in Schleswig-Holstein. ((Tobar et al. 2019).

While the European Truck Platooning Challenge as a project was a success, it demonstrated the difficulty in affecting the coordination and authorisation of multiple authorities, and in the case of Germany, more than one application within the same country where the testing crossed local regional borders.[24] The testing of autonomous vehicles in cross-border regions raises questions not only of horizontal coordination but also of vertical coordination between tiers of

[23]The ongoing L3 Pilot has projected some cross-border pilots in its methodology <https://l3pilot.eu>
[24] Such as between Southern and North Germany which involved applications to the Traffic Ministry, the Bavaria Interior Ministry and the Schleswig- Holstein and National Authorities for North Germany

government (Hamedinger 2011). The present regulation framework of each European country and each regional government has been created by historical events taking place over centuries (Medeiros 2019), and are not easily displaced. However this ad-hoc political and administrative framework across Europe arguably hinders the formation of efficient cross-border initiatives procured through cross-border research (Cavallaro 2019).

The testing of prototype vehicles across European borders is difficult due to barriers caused by a lack of legal and administrative coordination between countries. Although such difficulties may be circumvented by constraining pilot sites to one jurisdiction,[25] this deprives pre-deployment research of potential insights gained from pilots crossing geographical and jurisdictional boundaries.

6. Pan-European initiatives

An alternative regime to the ad-hoc framework for prototype vehicles is a harmonised pan-European regime which could address some aspects of the difficulties associated with cross-border tests. The first relates to experimental autonomous vehicle functions where these depart from existing type-approved vehicle components, which require an exemption following a satisfactory examination to ensure public safety. There is potential for minimum safety parameters to be agreed for autonomous vehicle testing, where one jurisdiction inspects and approves the functions of a pilot vehicle, whereupon other participating jurisdictions rely on the original jurisdiction's assurance that the vehicle meets minimum standards and will not cause a threat to the public. A regime for harmonised European type-approval exemptions has already been developed for commercially-ready autonomous vehicles, and may provide a blueprint for cross-border prototypes in Europe. Type-approval exemption for vehicles intended for the commercial market is subject to a different process for approval than prototype testing. Prototype testing is performed for research purposes, to test the limits of a product and to trial new technology. Approving vehicles for sale to the public necessarily focuses upon matters of safety and standardisation. Nevertheless, there may be synergies transferable to the prototype testing and exemption process. Guidelines developed by the European Commission ('the Guidelines') specifically target the country-by-country ad-hoc nature of exemption assessments by harmonising safety requirements, and streamlining mutual recognition of

[25] In addition to AUTOPILOT, examples of European projects operating pilots in multiple European counties which do not conduct cross border testing include; Co-Exist https://www.h2020-coexist.eu; AUTOC-ITS<https://www.autocits.eu>

exemptions for automated vehicles throughout Europe (EC 2019). Under the Guidelines manufacturers apply to one member state addressing requirements related to system performance, transition of driving tasks, emergency safety manoeuvres and cybersecurity. Once approved, the assessment may be mutually recognised in accordance with European Directive (European Parliament 2007) and placed on the EU market. [26] This process may be relevant to the approval of exemptions for prototype vehicles. If similar minimum requirements were formulated in respect of prototype vehicles, a pan-European prototype exemption regime may be developed whereby one authority in one state could approve a prototype vehicle to be used in multiple jurisdictions. A pan- European prototype testing regime may also address the structure and implementation of autonomous vehicle tests. Matters to be addressed could include edge cases,[27] the infrastructure required, requirements of the driver/operator and the liability and obligations of the developer. Such parameters were identified by the European Truck Platooning Challenge which recommended a common 'building blocks' exemption process for truck platooning, regarding the necessary criteria including; the applicant, the driver, the vehicle, the infrastructure, the documentation, field operational tests and code of practice (Tobar et al. 2019).

The coordination of infrastructure and administrative matters relating to test organisation. occurring over borders cannot be approved unilaterally by one jurisdiction. Pilots may involve roads, bridges, traffic lights, tunnels, cellular and internet connectivity under the control of another jurisdiction. A proposed autonomous vehicle test case, its planned route and the infrastructure involved requires cooperation between jurisdictions. There have been developments in cooperative European autonomous vehicle projects which indicate a coordinated regime could be implemented more widely. There are several examples of cross-border interoperability corridors, although at present such schemes are limited to small groups of jurisdictions.[28]

[26] The procedure would involve the Member State submitting a file of documents to the Technical Committee of Motor Vehicles on matters such as how the vehicle deviates from current type-approvals, the safety measures undertaken, and the results of relevant tests

[27] Edge cases test the vehicles in challenging conditions and better simulate how the technology would perform in the 'real world'

[28] Such as C-Roads <https://www.c-roads.eu/platform.html>

The interoperability of autonomous vehicle infrastructure is high on the agenda for European regulatory bodies. For example, the C-Roads Platform was launched by the European Commission in 2016 to help create harmonised intelligent transport deployment activities, through joint development and shared technical infrastructure to verify interoperability through cross-site testing.[29] However this programme does not negate the requirement for legal permissions to be obtained for prototype autonomous vehicles to travel across borders. Trial 5G networks have been established along cross-border corridors including a France/Germany/Luxembourg collaboration between Metz, Merzig and Luxembourg, a German and Italian link between Munich and Bologna via the Brenner Pass, and a collaboration between Spain and Portugal between Porto Vigo and Evora-Merida (EC 2018). While these corridors address aspects of the infrastructure required for testing, administrative and legal hurdles persist. The issue of improved cross-border cooperation has been identified by the European Commission's Cooperative Connected and Autonomous Mobility ('CCAM') Single Platform, in line with the Letter of Intent from Rome signed by 29 European countries on the testing and large-scale demonstrations of connected and automated driving (EC 2017). The aim of the CCAM is to support pre-deployment of open road testing in Europe. Priorities include to define an agreed list of common use-cases and functionalities, and a legal framework (EC CCAM n.d) however at the time of writing, the details of what such a framework might look like, is unknown.

Despite cross-border initiatives, it remains difficult for developers to plan and execute tests across borders. However there may be scope for the international administration of some of the legal and logistical barriers to cross-border testing activity. Coordination efforts could potentially be carried out by a Euroregion or similar organisation.

7. Euroregions

Euroregions are organisations covering geographical areas formed by adjoining regions belonging to two European countries to promote cooperation and development in that area (Perkmann 2012), an example being Sønderjylland-Schleswig between Germany and Denmark.[30] Euroregions are mostly concerned with administrative matters demanding cross-border coordination at the regional and local levels, which can include spatial planning and

[29] Cooperative, connected and automated mobility (CCAM) https://ec.europa.eu/transport/themes/its/c-its_en
[30] Sønderjylland-Schleswig Euroregion < https://www.region.dk/region/dk/>

transport (Medeiros 2011), such as a cross-border shuttle service between the Netherlands and Germany.[31] At present, Euroregions have little relevance, if any to the coordination of cross-border autonomous vehicle testing or the establishment of regulatory sandboxes to allow autonomous testing to legally occur between jurisdictions. A regulatory sandbox allows developers to run tests where some laws have been temporarily suspended, under certain conditions. Generally, within sandboxes, fines and penalties are not enforced for acts of good faith, allowing developers to pursue innovation (Knight 2016), while remaining responsible for damage or injury sustained during testing. A sandbox may allow developers to properly test their technology while still maintaining minimum standards to protect road users. A 'test and learn' framework may ultimately encourage improvements and pave the way for better products (Pratt 2017). Sandbox conditions are normally granted in the pursuit of explicit learning objectives, and at the completion of the test, the laws apply as normal. The administration of a sandbox can also provide bespoke guidance on interpreting or complying with regulation, and the extent of the testing parameters (Ofgem 2018).

At present, a scheme for the coordination of regulatory sandboxes for cross-border prototype testing has not been established. The role of Euroregions is currently underdeveloped for the purpose of autonomous vehicle testing and the formation of regulatory sandboxes. This may be because Euroregions are not formed upon a set criteria, and in some cases lack legal personality operating only on an informal basis, subject to inconsistent governance structures of a principal member state or regional authority. The full potential of such organisations has yet to be achieved, both in terms of ideal governance and activities (Dura 2018). However it remains that a coordinated border region may be part of the solution to the improvement of European cross-border testing in the future. Close cooperation between regional regulators on live regulatory sandbox projects, could promote regulatory harmonisation and enhance development (Golden 2018). Coordinating regulation across multiple jurisdictions may reduce the cost and complexity for researchers attempting to cross national or subnational borders. A mechanism promoting dialogue between jurisdictions specifically addressing issues relevant to autonomous vehicles may be useful in accommodating regional differences (International Transport Forum 2015). A framework which emphasises discourse and cooperation between European countries may be more beneficial than a strict codified central regime. Codifying requirements for prototype testing too firmly, may inflict an effect as inhibiting upon

[31] NL/GER (province Gelderland; www.i-at.eu)

innovation as the current regime of multiplication and duplication. Countries and regions with prescriptive testing regimes are not necessarily ahead of those without one.[32] Consequently cross-border test areas could benefit from being administered by a coordinating authority which is able to facilitate information exchange and problem solving between member states interested in working together.

8. Conclusion

Globally, intense research is taking place to develop safe and reliable autonomous vehicles. The potential individual and societal benefits associated with the widespread deployment of autonomous vehicles have galvanised researchers and developers to institute autonomous driving research projects. The data arising from prototype research will contribute to the production of reliable autonomous technology being released onto the commercial market, operating safely in varied driving conditions encountered on public roads. The diverse geography, climate and languages of Europe potentially provides researchers with a usefully challenging platform on which to improve their products to a competitive level. Pilots would also provide an opportunity to consider how current national and international rules apply to autonomous vehicles and whether changes to regulation are necessary.

However in Europe, prototype pilots are usually siloed to a single jurisdiction due to the logistical and legal challenges encountered with research crossing jurisdictional borders. Across Europe there are different approaches to prototype testing on the national and regional level which causes considerable legal and administrative complications. There may be less cross-border testing taking place due to these issues, slowing down the progress of European research. Currently type-approval exemptions for prototype testing is not authorised at the pan-European level, and testing which involves multiple countries comprises of duplicated type-approval exemption processes. A European framework for the mutual recognition of type-approval exemptions issued for the purposes of prototype testing may be a useful, partial solution to the problem of duplicated exemption certificates. In respect of the route and infrastructure required for the test itself, there is no streamlined European-wide process allowing the organisation of pilots on public roads. There may be scope for cross-border organisations to coordinate the infrastructure and the regulatory sandboxes required for tests to

[32] In the UK, organisations wishing to test connected and autonomous vehicles can test on any UK road without requiring a permit, licence or other documentation, as long as they obey all relevant road traffic laws (Centre for Connected and Autonomous Vehicles 2019)

take place across jurisdictional borders, and to facilitate cooperative dialogue between member states.

The vision for Europe's future includes autonomous vehicles being used in transport and commuter links between countries. For Europe to stay abreast of international competition in autonomous vehicle development, it is essential that barriers to cross-border testing are resolved.

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References

Armingol JM & Ors 'Environmental Perception for intelligent vehicles' *Intelligent Vehicles: Enabling Technologies and Future Developments*, Felipe Jimenez (ed) Elsevier (2018) 53

Arrúe, A and R Heras (2018) *Guidance on National Testing Regulations.* CARTRE Deliverable D3.8.
CARTRE is an EU H2020 project: *Coordination of Automated Road Transport Deployment for Europe*, GA number 724086

Association of European Border Regions, 'Information services for cross-border workers in European border regions' (2012)

Austriatech, 'Test Applications'< https://www.austriatech.at/en/testantraege-kontaktstelle/ > last visited 10 September 2019 (undated)

AUTOPILOT <https://autopilot-project.eu> Acknowledgment: This work was supported in part by AUTOPILOT project under Grant H2020/731993, and EU PAsCAL project under Grant H2020/815098

Beating the Heat: Thermal Testing in Death Valley *Medium* (14 July 2017)

Bomey N and T Zambito, 'Regulators scramble to stay ahead of self driving cars' *USA Today* (25 June 2017)

Braunerhielm L, E Alfredsson Olsson & E Mederros, 'The importance of Swedish-Norweigan birder residents' perspectives for bottom-up cross-border planning strategies' (2018) 73(2) Norsk Geografisk Tidsskrift- Norwegian Journal of Geography 96

Bundesministerium für Verkehr and digitale Infrastrktur (Germany) 'Franco-German – Luxemburgish cooperation on automated and connected driving, Concept for the Cross-Border Digital Test Bed'

Burgess M 'What is the internet of things?' *Wired* (January 2017)
< https://www.wired.co.uk/article/internet-of-things-what-is-explained-iot>

Cavallaro F & A Dianin, 'Cross-Border Commuting in Central Europe: features, trends and policies' (2019) 78 Transport Policy 86

Centre for Connected and Autonomous Vehicles (United Kingdom) A Code of Practice: Automated Vehicles Trialling' (2019)

Christodoulou A and P Christidis, 'Cross-border transport infrastructure in the EU: A methodology to assess the role of cross-border road networks' (2018) European Commission-JRC Science for policy report

Davila A, E Aramburu and A Freixas, 'Making the Best Out of Aerodynamics: Platoons' *SAE International* (4 August 2013)

'Driverless Cars might follow the rules of the road, but what about the language of driving?'

The Conversation (8 January 2018)

Dura A, F Camonita, M Berzi and A Noferini, 'Euroregions, Excellence and Innovations across EU borders. A Catalogue of Good Practices' (2018) Department of Geography, UAB, Barcelona

European Commission (2015) 'Cross Border Cooperation in The European Union: an opportunity for Europe's border regions'

European Commission FAQ- Type Approval of Vehicles <https://ec.europa.eu/growth/sectors/automotive/technical-harmonisation/faq-auto_en> last visited 15 September 2019

European Commission (2017) Letter of Intent on the testing and large-scale demonstrations of connected and automated driving (Rome)

European Commission (2017) 'Europe on the Move: An Overview of the EU Road Transport Market in 2015' DG for Mobility and Transport

European Commission (2019) Guidelines on the exemption procedure for the EU approval of automated vehicles (Version 4.1 Supported by the Technical Committee on Motor Vehicles)

European Commission: Guidelines on the exemption procedure for the EU approval of automated vehicles (Version 4.1 Supported by the Technical Committee on Motor Vehicles of 12 February 2019) <https://ec.europa.eu/growth/content/guidelines-exemption-procedure-eu-approval-automated-vehicles_en>

European Commission, Cooperative, connected and automated mobility 'Cooperation on cross-border testing of CCAM' https://ec.europa.eu/transport/sites/transport/files/its-committee-cross-border-testing-scoping-document.pdf

European Commission: Connected and automated mobility: three 5G trial projects to be launched at ICT 2018 event (30 November 2018) https://ec.europa.eu/digital-single-market/en/news/connected-and-automated-mobility-three-5g-corridor-trial-projects-be-launched-ict-2018-event

Federal Ministry Republic of Austria 'Austrian Action Programme on Automated Mobility' 2019-2022

Fontes MJ, A Ribeiro and J Silva, 'Accessibility and Local Development: Interaction between Cross-border Accessibility and Local Development in Portugal and Spain' (2014) 111 Procedia-Social and Behavioural Sciences 927

Gödeske C 'Men in Hats: East Germany's Cult Pedestrian Signal Turns 50' *Spielgal Online* (6 October 2011)

Golden P, quoting Gina Conheady of A&L Goodbody in: 'Obstacles pepper path to pan-European sandbox *Euromoney* (25 January 2018)

Government of the Netherlands, The Truck Platooning Challenge 2016 (ETPC):

https://www.government.nl/documents/leaflets/2015/10/06/leaflet-european-truck-platooning-challenge-2016

Government of the Netherlands, Declaration of Amsterdam 'Cooperation in the field of connected and automated driving' (14 April 2016)

Government of Luxembourg, The Franco-German-Luxemburgish cooperation on automated and connected driving, concept for the cross-border Digital Test Bed (2018) <https://gouvernement.lu/fr/publications.gouv_meco%2Bfr%2Bpublications%2Bbrochure-livre%2Bcross-border-digital.html>

Hamedinger A, 'Challenges of governance in two cross-border city regions: "CENTROPE" and the "EuRegio Salzburg- Berchtesgadener Land- Traunstein' (2011) 4(2) Urban Research & Practice 153

Harper C, C Hendrickson, S Mangones, C Samaras, 'Estimating potential increases in travel with autonomous vehicles for the non-driving , elderly and people with travel-restrictive medical conditions' (2016) 72 Transportation Research Part C: Emerging Technologies 1-9

Hojjati-Emami K, B Dhillon, K Jenab, 'Reliability Prediction for the vehicle equipped with advanced driver assistance systems (ADAS) and passive safety systems (PSS)' (2012)3 International Journal of Industrial Engineering Computations 731

International Federation of Accountants and Business at OECD, 'Regulatory divergence: Costs, risks, impacts' (February 2018) 4

International Transport Forum, 'Automated and Autonomous Driving: Regulation under uncertainty' (2015)

Kalra N and S Paddock, 'Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?' in *Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability* (Rand 2016)

Kalra N and DG Groves, 'The Enemy of Good: Estimating the Cost of Waiting for Nearly Perfect Autonomous Vehicles' (RAND Corporation 2017)

Knight B, 'Innovation Will Stall Without a Regulatory Fintech "Sandbox" (2016) 181 American Banker 221

Medeiros E, 'Cross-border transports and cross-border mobility in the EU border regions' (2019) 7 Case Studies in Transport Policy 1

Medeiros E, '(Re) defining the Euroregion Concept' (2011) 19(1) European Planning Studies 141

Medium: 'Beating the Heat: Thermal Testing in Death Valley *Medium* (14 July 2017)

Ofgem, 'What is a regulatory sandbox' *Ofgem* (September 2018)

Perkmann M, 'The rise of the Euregio. A bird's eye perspective on European cross-border cooperation' (2002) Department of Sociology, Lancaster University, Lancaster

Pearah, P 'Opening the Door to Self Driving Cars: How this will change the rule of the road' (2017) (18) High Tech 40

Prakken H 'On the problem of making autonomous vehicles confirm to traffic law' (2017) 24 Artificial Intelligence Law 341

Pratt A, 'The benefits of a regulatory sandbox' (2017) 181 (21) Veterinary Record 573

Radecki P and M Campbell, 'All Weather Perception: Joint Data Association Tracking and Classification for Autonomous Vehicles' (2016) Arxiv ID: 1605.02196

RDW, 'Assessment Framework Method and Process: Connected and/or Automated Driving on Dutch Public Roads (2 July 2017)

Roderick D, 'How Far Will International Economic Integration Go?' (2000) 14(1) Journal of Economic Perspectives 177

SAE J3016_201806 <https://www.sae.org/standards/content/j3016_201806/>

Steck F, V Kolarova, F Behamonde-Birke and Ors, 'How Autonomous Driving May Affect the Value of Travel Time Savings for Commuting' (2018) 2672 (46) Transportation Research Record 11

Stock K, 'Self Driving Cars Can Handle Neither Rain nor Sleet no Snow' (*Bloomberg Businessweek* 17 September 2018)

Tobar M, Estrella Martinez, Oriol Flix, Guillermo Gonzalez and Ors (2019) 'ENSEMBLE Regulatory Framework- State of the Art' EMSEMBLE Deliverable 6.1. ENSEMBLE is a EU Horizon 2020 Project: Enabling Safe Multi-Brand Platooning for Europe GA No 724086

The Conversation: 'Driverless Cars might follow the rules of the road, but what about the language of driving?' *The Conversation* (8 January 2018)

Ttnews: VW Joins BMW in testing Self-Driving Cars on German City Streets *ttnews.com* (3 April 2019) <https://www.ttnews.com/articles/vw-joins-bmw-testing-self-driving-cars-german-city-streets>

Vellinga N, 'From the testing to the development of self-driving cars: Legal challenges to policy makers on the road ahead' (2017) Computer Law and Security Review 33(6) 847

Zhao D, H Lam, H Peng, S Bao, D LeBlanc and Ors, 'Accelerated Evaluation of Automated Vehicle Safety in Lane-Change Scenarios Based on Importance Sampling Techniques' (2017) 18(3) Transactions on Intelligent Transportation Systems 595

Republic of Austria

Federal Constitution, Art 118 (Republic of Austria)

Federal Ministry Republic of Austria, 402nd Ordinance of the Federal Minister for Transport, Innovation and Technology on the Framework for Automated Driving (Autonomous Driving Regulation- AutomatFahrV)

European Parliament

European Parliament Directive 2007/46/EC on the approval of motor vehicles (Article 20) to be replaced by Regulation (EU) No. 858/2018 on vehicle approval and market surveillance) (Article 39) from 1 September 2020.

United Nations

United Nations Economic Commission for Europe (1968) Vienna Convention on Road Signs and Signals

UN Regulation 79, Addendum 78, Revision 4 (7 November 2018)
Agreement Concerning the Adoption of Harmonised Technical Requirements for Wheeled Vehicles