Autonomous Driving
Regulatory Issues:

Participating Partners:
Kapsch TrafficCom, Michelin, Nissan, PTV Group, Volvo

External Expert:
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Depending on how you look at it, humans are either the worst or the best drivers out there. In the near-term future, they may not be the only drivers out there.

They are the worst because they make many avoidable mistakes, attempt to drive while incapacitated, are prone to speeding and misjudging the road environment and overestimate their capacity to handle the dynamic driving task. Over 90% of road crashes are associated with human error and this toll weighs heavily on society in human and economic terms.

Human drivers are nonetheless quite good at driving. In the United States, cars drive 3.3 million hours for every fatal crash and 64 400 hours for every injury crash – that means the vast majority of the time, humans make micro-decisions that keep themselves and others safe.

Improved safety is perhaps the greatest potential benefit that may result from high levels of automation in vehicles. The real challenge, however, is not to create autonomous vehicles that avoid human mistakes, but rather to create autonomous vehicles that replicate the good driving performance of humans.

Automation also promises to improve traffic flow in cities, reduce parking needs, reduce driver stress and allow more optimal and intensive use of infrastructure. These potential benefits, however, remain untested at large scale and authorities should keep this uncertainty in mind as they develop policies which may result in unexpected outcomes.
Future obsolescence of the drivers license
How to prepare for autonomous driving?

Children born today may never need to get a driving license to use a car ... their children may not be able to.

Many cars sold today are already capable of some level of autonomous operation and prototype cars capable of driving autonomously have been and continue to be tested on public roads in Europe, Japan and the United States. These technologies have arrived rapidly on the market and their future deployment is expected to accelerate.

With the uptake of on-road autonomous driving being years rather than decades away, authorities will have to adapt existing rules and create new ones in order to ensure the full compatibility of these vehicles with the public’s expectations regarding safety, legal responsibility and privacy. Fundamental changes will be brought about by growing vehicle automation; children born today may never need to get a driving license to use a car, their children may not be able to. This project looks at what issues will have to be considered at a strategic level by authorities as autonomous vehicles arrive on our roads.

We undertook this study on the basis of meetings and discussions amongst project partners, desktop research and invited the contribution of an external expert – Bryant Walker Smith, of the University of the South Carolina School of Law and the Center for Internet and Society at Stanford Law School.
Automated driving comprises a diverse set of emerging concepts that must be understood individually and as part of broader trends toward automation and connectivity.

Automated driving encompasses a wide range of technologies and infrastructures, capabilities and contexts, use cases and business cases, and products and services. There is no single timeline for these developments: Some are here today, some may be distant, and some will depend on specific technical innovations or particular policy choices.

Importantly, vehicle automation is part of much larger revolutions in automation and connectivity. The recent hallmarks of these revolutions—personal computers, mobile telephones, and the Internet—have converged with each other and are now blending with machines that sense and manipulate the physical environment. These machines include not just automated motor vehicles but also drones, personal care robots, 3D printers, surveillance devices, and many others. While addressing only road vehicle automation, this report strives to anticipate these broader changes in both technology and society.
An automated vehicle, like a human, must collect information, make a decision based on that information, and execute that decision. Information comes from vehicle equipment, physical infrastructure, physical-digital infrastructure, and digital infrastructure, any of which may be public or private. The increasing ability for vehicles to sense, plan, act and communicate rests on a number of technologies... many of which are mature or are rapidly maturing.

**Location:** Global navigation satellite systems provide core location data, augmented by other precision-boosting technologies using cellular communications infrastructure and WiFi network maps.

**High definition maps:** These allow to situate a vehicle into a context: what type of road, which lane, what are the rules applying to the use of that space (including speed limits and direction of travel)? They also allow vehicles to anticipate what may come next. These maps are both used and continuously updated by the vehicles themselves.

**Sensing:** A number of technologies allow vehicles to perceive their surroundings. These include high-definition video cameras, ultrasonic sensors, laser scanners and radar technology. Costs for these can be substantial but are expected to decrease with market scale-up.

**Processing:** Data processing costs have decreased substantially while their speed has increased. The development of more sophisticated algorithms and the arrival of merged sensing/processing microchips will improve the ability for vehicles to sense and rapidly act.

**Communicate:** Data transfer technologies and protocols are under development but are not yet harmonised. Dependence on vehicle-to-vehicle and vehicle-to-infrastructure communications may vary among early autonomous vehicle models.
### SAE International’s Levels of Driving Automation

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Name</th>
<th>Description</th>
<th>Steering, acceleration, deceleration</th>
<th>Monitoring driving environment</th>
<th>Fallback performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No automation</td>
<td>Full time performance of the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>Driver assistance</td>
<td>The driving mode specific execution by a driver assistance system of either steering or acceleration-deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial automation</td>
<td>The driving mode specific execution by one or more driving assistance systems of both steering and acceleration-deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>3</td>
<td>Conditional automation</td>
<td>The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High automation</td>
<td>The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full automation</td>
<td>The full time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environment conditions that can be managed by a human driver</td>
<td></td>
<td></td>
<td></td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

1 SAE Society of Automotive Engineers
The ability for vehicles to sense and act in response to their environment is spread along a continuum of autonomous capabilities. SAE International’s Levels of Driving Automation capture the emerging descriptive consensus most systematically. These levels are descriptive rather than normative, technical rather than legal, imply no particular order of market introduction and indicate minimum rather than maximum system capabilities for each level.

SAE’s levels primarily identify how the “dynamic driving task” is divided between human and machine: It is performed entirely by a human driver at level 0 (no automation) and entirely by an automated driving system at level 5 (full automation). In the “mushy middle,” this task is shared simultaneously or sequentially, raising difficult questions of human-machine interaction.

Current deployment and development necessarily focus on this middle. This is because full automation, “the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver,” remains elusive. Human drivers confront, and usually manage, an incredible variety of contexts—geographic areas, roadway types, traffic conditions, weather conditions, and events/incidents—for which automated vehicles have yet to be designed and demonstrated.

1 SAE Society of Automotive Engineers
Encrypted data signatures ensure trustworthy communications amongst connected devices.
Some automation pathways emphasise greater connectivity amongst vehicles, between vehicles and infrastructure, and between vehicles and other road users including pedestrians and cyclists. That connectivity would serve to enhance safety and improve traffic flow by exchanging information on the location, heading, speed and possible immediate future actions to be initiated by vehicles. Benefits from connectivity scale as more vehicles are connected but that strength is also a weakness – connectivity must be protected from abuse.

The challenges are threefold: messages must be authenticated as real, they must verifiably be shown to have come where they say they come from and personal data must not be divulged.

Protocols based on encrypted data signatures can meet all three challenges. These protocols ensure trustworthy communications amongst connected devices since authentication of messages and senders is based on a secure key. Ensuring the inviolate nature of that key is a crucial role and one that should be entrusted to a neutral party. These protocols also ensure the protection of personal data by ensuring that data cannot be read without the authorised use of a key. This enables data use rules to be hard-coded to keys that are issued – for instance a key allows the decryption of data for a limited period of time only.

Nonetheless, even with encrypted security protocols in place, some risks may remain. In this context, allowing remote access to the vehicle sub-systems responsible for steering, speed and braking may be an inherently risky strategy and should likely be avoided.
2 automation strategies

“something everywhere”
Improve the automated driving systems available in conventional vehicles so that human drivers can shift more of the dynamic driving task to these systems.

“everything somewhere”
Deploy vehicles without a human driver and gradually expand this operation to more contexts.
Efforts toward full automation tend to follow one of two incremental paths. The first involves gradually improving the automated driving systems available in conventional vehicles so that human drivers can shift more of the dynamic driving task to these systems. The second involves deploying vehicles without a human driver and gradually expanding this operation to more contexts. These two approaches can be simplistically described as "Something Everywhere" and "Everything Somewhere."

In addition, automation will likely be deployed in two types of road vehicles simultaneously. While much focus has been placed on growing car automation, some promising early applications of highly autonomous operation may involve heavy-duty vehicles and buses operating on specific routes (e.g. bus rapid transit or container shuttles on dedicated facilities), in certain areas or in certain conditions (e.g. motorways at night).
The “Something Everywhere” strategy is generally embraced by traditional car manufacturers. Many of today’s production vehicles are capable of driver assistance (level 1), typically through the use of adaptive cruise control to adjust speed based on following distance. A small number of vehicles also incorporate an active lane-keeping feature, parking assist or traffic jam autonomous driving in a way that makes them capable of partial automation (level 2). Notwithstanding the potential for and reality of driver distraction, both of these levels assume that the human driver continues to actively monitor the driving environment.

The introduction of conventional cars and trucks capable of operating without this active monitoring will represent a significant technical and conceptual leap. Because of its assumption that the human driver will resume actively driving shortly after being prompted to do so, conditional automation raises particularly difficult issues of human-machine interaction that have not been satisfactorily solved.

High automation (level 4) is nonetheless challenging because it describes an automated driving system that, once engaged, can always revert to a “minimal risk condition” should a human driver not resume actively driving. Reverting to this minimal risk condition may be easier in some contexts, like low-speed parking facilities, than in others, like urban expressways. For this reason, a highly automated driving system is capable of operating in some, but not necessarily all, contexts.
Autonomous Driving: Regulatory Issues

Why

What we did

What we found

Image: Induct/Rand
High automation (level 4) is where the “Everything Somewhere” strategy begins. The custom vehicles that currently operate without any real-time input from human drivers are limited to highly specific contexts, including particular routes and low speeds.

A key challenge is expanding these vehicles to more geographic areas, roadway types, traffic conditions, weather conditions, and events/incidents. One developer, for example, might initiate a pilot project in which its vehicles operate in good weather at neighbourhood speeds along a carefully mapped, maintained, and monitored corridor within its corporate campus. It might then expand this pilot to select streets within its local community and, later, to a handful of other communities. As the developer improves its technologies and increases public confidence in them, it might deploy its vehicles at higher speeds and on more roadway types.

Such a system of automated vehicles might eventually function in many traffic and weather conditions on many roads in many communities. Nonetheless, these vehicles would not reach full automation (level 5) unless they handled “all roadway and environmental conditions that can be managed by a human”.

...or everything somewhere
Partial Autonomy: Advanced driver assistance, motorway operations and platooning

Use and business cases are linked to automation strategies. The “Something Everywhere” strategy for conventional cars and trucks points to increasingly sophisticated advanced driver assistance systems that are marketed in terms of safety, fuel efficiency, driver comfort, driver convenience, and ultimately driver productivity (assuming these benefits are realised).

Motorway automation may be an early use case for conditional or high automation in conventional vehicles. Although speeds are high, motorways tend to be more uniformly designed and better maintained. Vehicle flows are more organised, and bicyclists and pedestrians are generally absent.

Dedicated facilities are occasionally proposed for automated motorway vehicles, but retrofitting existing facilities is likely to be prohibitively expensive and may ultimately prove unnecessary. Separation may be more viable on newly constructed roadways in rapidly urbanising countries, on existing managed lanes (such as those for high-occupancy vehicles) between major employment and residential areas, and on specialised facilities serving exceptionally large numbers of trucks.

Vehicle platoons are a particularly promising application for motorways. A platoon consists of two to six cars or trucks that are closely spaced and tightly coordinated through both vehicle-to-vehicle communication and some degree of automation. A driver may sit in each vehicle, in only the lead vehicle, or eventually in none of the vehicles. Benefits may include significant fuel savings and, for fleet operators, potentially lower labour costs.
Autonomous Driving: Regulatory Issues

Why

What we did

What we found

Image: http://www.airportsinformationblog.co.uk/
Many urban and suburban applications, however, might be realized earlier through an “Everything Somewhere” strategy of non-conventional vehicles. Passenger shuttles and taxis might operate at low speeds in central business districts, corporate campuses, university campuses, retirement communities, resorts, shopping malls, airports, and other semi-enclosed environments as well as for first- and last-mile public transport applications. Delivery shuttles might likewise travel at low speeds along particular routes and at particular times.

Some of these urban applications may benefit from specialised infrastructure. Physical infrastructure might include vehicle-to-vehicle and vehicle-to-infrastructure communications equipment. Digital infrastructure might include the maintenance of highly detailed roadway maps and pertinent traffic operations data. This specialised infrastructure, if actually required, could be limited to a manageable set of corridors actually used by a particular urban mobility system.

Whereas wealthy consumers and fleet operators are likely to be early adopters of “Something Everywhere” vehicles, an “Everything Somewhere” approach might reach a more diverse group of users. Especially if its fuel and labour costs are lower and its usage is higher, an extensive urban mobility system might compare favourably with private vehicle ownership, conventional taxis, and conventional public transport. Residents who cannot afford to buy and maintain a private car or who are unable to drive may be some of the earliest adopters of these shared systems.
Autonomous Driving: Regulatory Issues

**Regulatory tools**

- **Public**
  - Regulatory performance standards
  - Regulatory process requirements
  - Regulatory entry barriers
  - Criminal and civil sanctions
  - Mandatory and quasi-mandatory recalls
  - Investigations and hearings

- **Private**
  - Private standards
  - Industry practice
  - Conditions of insurance
  - Tort and warranty claims
  - Reputation
  - Sales

- **Ex-ante**
  - What we did

- **Ex-post**
  - What we found

- **Why**
  - What we did
  - What we found
Some jurisdictions have implemented laws, licensing requirements or rules to govern the testing of autonomous vehicles or allow the on-road use of some partial vehicle automation technology. To our knowledge, no jurisdiction has taken anticipatory action to change the regulatory structure surrounding some likely use cases for fully autonomous vehicles—e.g. in providing long distance road haulage or shared, taxi-like and quasi-public transport services. The latter two are highly regulated sectors that could face significant disruption from the arrival of self-driving vehicles.

Passing laws is just one of many potential regulatory tools for governments to consider.

Encouraging desirable conduct and deterring undesirable conduct are among the most important goals of regulation. In a narrow sense, regulation is simply the enactment of a binding rule by a public authority. This narrow definition, however, denies other key regulatory tools that warrant attention. Any of these other tools could impact whether automated driving systems are deployed and, if they are, what kinds, when, where, how, and by whom. For example, imposing an insurance requirement on developers of automated vehicles, as several US states have now done, could advantage larger companies that self-insure as well as private insurers to whom smaller developers may turn.
Governments may face unexpected obligations to act early

Motorists and motor vehicles already pass through a number of regulatory gates. For transportation products, particularly noncommercial vehicles, these can include first sale (which typically requires manufacturers to either self-certify or to obtain type approval), vehicle registration and subsequent renewal by the owner, driver licensing and subsequent renewal for the operator, provision of vehicle insurance, traffic and vehicle enforcement, investigations into vehicle defects, recall of vehicles or components that are not reasonably safe, and litigation over traffic injuries and fatalities.

For transportation services, including public transit, taxicab operations, and commercial trucking, these gates can include all of those listed above as well as construction of facilities, procurement of rolling stock, awards of concessions, and funding of projects and programmes.

These gates enable governments to monitor, influence, or impede particular vehicle automation concepts. They may also obligate public actors to address automation sooner than they are ready. For example, a driver licensing agency may receive an application from a disabled person who cannot legally drive under existing rules but who asserts the right to operate an automated vehicle under an accommodations law. Another example could be a transportation agency that has completed a benefit-cost assessment for a major infrastructure project facing a legal challenge because it failed to account for the impacts of automation on demand, capacity, and revenue assumptions.
Regulatory Considerations: Key Policy Choices (1)

**Treat automated vehicles specially or generally?**

Authorities seeking to regulate automated driving could carefully examine and, as needed, modify existing laws to clarify their application to vehicle automation. Alternatively, they could promulgate a specific package of largely standalone rules that apply exclusively to vehicle automation and intentionally differentiate between automated and non-automated driving with respect to particular rights, obligations, and liabilities.

A general approach seems more appropriate as automation becomes more widespread and ordinary. Nonetheless, a specific approach may be a simpler and cleaner method of addressing a nascent set of technologies that require development of particular expertise.

**Let policy lead or technology lag?**

Proactive policy, including specific rules, can provide companies the legal clarity they need to make investment and deployment decisions. Nonetheless, prematurely codifying requirements can freeze unrealistically high or low expectations into the law. Furthermore, duplicative or repeat efforts to develop rules can force developers to invest resources in lengthy regulatory processes.

For these reasons, informal dialogue may often be preferable to specific rules in early stages of technology development. Importantly, countries and regions with a specific "automated driving law" are not necessarily ahead of those without one. The US state of Michigan, for example, recently enacted a law that explicitly prohibits the operation of automated vehicles for any purpose other than research and development testing. Where other jurisdictions may have flexibility to accommodate new kinds of pilot projects that do not qualify strictly as testing, Michigan will have none.
Privilege uniformity or flexibility?

Uniform regulation across multiple jurisdictions can reduce the cost and complexity for developers of systems that will necessarily cross national or subnational borders. Designing for one set of rules and roads is daunting enough; designing for dozens only amplifies this challenge.

Flexible regulation, however, might more easily accommodate existing regional differences, local startups, and unique demonstration projects. It may also foster more national ownership over what is viewed by some as an area of interstate competition.

Emphasise ex-ante or ex-post regulation?

The choice between ex ante regulation (particularly regulatory standards) and ex post regulation (particularly recalls and civil suits) also implicates flexibility. Forward-looking rules provide more certainty but less flexibility; backward-looking measures provide more flexibility but less certainty. These tradeoffs are particularly relevant to concerns raised about the liability of automated vehicle manufacturers and associated companies for injuries related to their products. These concerns, however, likely derive at least as much from technical uncertainty (how will these eventual products actually perform) as from legal uncertainty (how will courts determine liability)?
Automated driving comprises a diverse set of emerging concepts that must be understood individually and as part of broader trends toward automation and connectivity.

Vehicle automation is part of much larger revolutions in automation and connectivity. The recent hallmarks of these revolutions—personal computers, mobile telephones and the Internet—have converged with each other and are now blending with machines that sense and manipulate the physical environment. These machines include not just automated motor vehicles but also drones, personal care robots, 3D printers, surveillance devices and many others. Vehicles will change with growing automation but so too will their role in society in ways that are hard to foresee. Policies should account for this uncertainty and ensure sufficient resilience to adapt to these changes, or at a minimum, not block those that are desirable.

Uncertainty on market deployment strategies and pathways complicates the regulatory task.

Autonomous vehicle regulation should ensure safety and prevent, or at least mitigate, market failures. This task is complicated by uncertainty on what it is that should be regulated and the risk that regulation may in fact lock in one automation pathway over a potentially better one. Though regulators may target autonomous vehicles as a special case out of convenience, it may be preferable to adapt existing rules as much as possible.

Early regulatory action may be desirable but carries risks as well; prematurely codifying requirements can freeze unrealistically high or low expectations into the law in a way that ultimately causes that law to lag rather than to lead. Some regulatory flexibility seems desirable – allowing circumscribed uses such as low speed urban operation or motorway platooning before implementing a blanket set of rules.
Incrementally shifting the driving task to machines and algorithms and away from people will require changes in insurance...
Liability remains an important barrier for the manufacturers and designers of autonomous vehicles. Expanding public insurance and facilitating greater private insurance could provide sufficient compensation to those injured by an automated vehicle while relieving some of the pressure on the tort system to provide such a remedy. Enhanced vehicle insurance requirements by manufacturers, especially if combined with greater flexibility in the administration of this insurance, could also provide a third-party check on the safety of automated systems.

...and may have an impact on what information developers and manufacturers of autonomous vehicles share and with whom
Education of public actors and of the public at large is essential to the development of effective regulations and realistic expectations. Governments can facilitate this education by encouraging developers to share specific data about their products and processes in order to benefit from more flexible regulation. In some cases, it may be desirable to audit specific algorithms that directly impact public welfare – e.g. those that govern loss-loss decisions by automated vehicles.

Regulators and developers should actively plan to minimise legacy risks
Vehicles with automated driving systems that are introduced in the next few years will be neither perfect nor transitory. Years after these early models have become outdated, many of these vehicles will still be on the road. A key goal for both regulators and developers should be limiting the physical risk of these systems through a variety of technical and contractual tools to enable monitoring and over-the-air updates. Designing vehicles for sensor or other system upgrades may also help reduce legacy risks.
ABOUT THE INTERNATIONAL TRANSPORT FORUM

The International Transport Forum at the OECD is an intergovernmental organisation with 54 member countries. It acts as a strategic think tank with the objective of helping shape the transport policy agenda on a global level and ensuring that it contributes to economic growth, environmental protection, social inclusion and the preservation of human life and well-being. Until 2007 the organisation was known as the European Conference of Ministers of Transport (ECMT), then its geographic reach was widened and it became the International Transport Forum.

The International Transport Forum manages the Multilateral Licences for international road haulage on the European continent.

The transport policy related work of the International Transport Forum rests on three pillars

• Annual Summit
• Research Centre
• Corporate Partnership Board

CORPORATE PARTNERSHIP BOARD (CPB)

The CPB is a global network of companies from across all transport modes and closely related areas like energy, finance, IT, who understand the opportunities and challenges to transport and want to work with the ITF to improve policy analysis and advice by adding a corporate perspective to the process. The CPB provides a unique avenue for participating in the debate on the challenges and trends facing global transport, and bringing issues important to businesses to the attention of policy makers, key transport stakeholders in ministries, the business community, and international organisations.

The work started in early 2014 and there are currently four projects underway:

• Autonomous Driving: Regulatory Issues
• Urban Mobility: System Upgrade
• Mobility Data: Changes and Opportunities
• Drivers of Logistics Performance: Case Study

This is a background document, with the final report due January 2015.

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