PTOLEMUS
Consulting Group

2017 EDITION

THE AUTONOMOUS VEHICLE GLOBAL STUDY

Free abstract

The most thorough report on driverless vehicles

A perfect storm ready to wipe out risk

ABOUT PTOLEMUS CONSULTING GROUP

from Ptolemy, the Egyptian savant who built the 1st map of the world

PTOLEMUS is the first international strategy consulting & research firm specialised in the connected vehicle and the Internet of Things (IoT).

We help our clients apply strategic analysis to this fast-moving ecosystem, across all its industries (automotive, insurance, assistance, fleet management, road charging, mobile telecoms, etc.) and on an international basis.

PTOLEMUS, founded by Frederic Bruneteau, operates worldwide and is present in 9 countries: Belgium, Canada, France, Germany, Italy, Russia, South Africa, the UK and the US.

PTOLEMUS has performed nearly 100 consulting assignments related to connected and autonomous vehicles.

For any enquiry, please send a message to contact@ptolemus.com

Our consulting services

- Strategy definition
- Investment assistance
- Innovation management
- Procurement strategy
- Business development
- Deployment

Our fields of expertise

Mobility services	Car pooling Car sharing Smart parking	Multimodal mobility Ride hailing	Road side assistance Tax refund
Vehicle services & telematics	bCall eCall FMS SVT / SVR	Tracking VRM In-car Wi-Fi Fuel cards	Parking Navigation Speed cameras Traffic information
Usage-based charging	Car As A Service Electronic Toll Collection	Mobility-as-a-Service Road charging	UBI / PAYD Vehicle rental Vehicle leasing
Vehicle data & analytics	AI CAN-bus Crowd-sourcing Data protection	Driving behaviour OBD Predictive analytics	Remote diagnostics xFCD
Vehicle automation	ADAS	Autonomous cars	Autonomous trucks
Enabling technologies	Positioning (GNSS / WiFi / cellular)	M2M / connectivity Smartphones	Telematic devices V2X

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THE 10 AUTHORS OF THIS REPORT

Frederic Bruneteau, Managing Director, Brussels

MS, Management, HEC Paris and CEMS Master, University of Cologne

Mr. Bruneteau has accumulated 20 years of experience including 17 years of experience of the mobility domain and 8 years of strategic and financial advisory for company such as **Arthur D. Little**, **BNP Paribas, SFR Vodafone** and **TomTom.**

Having assisted dozens of clients such as Allianz, Generali, Telit, Michelin, Qualcomm and Toyota, he has become **one of the world's foremost experts in the field of telematics**, quoted by numerous publications such as *The Economist* and *the Financial Times*. He has spoken at more than 40 international conferences on the subject.

Within PTOLEMUS, he has **led 70 assignments related to connected & autonomous vehicles** for leaders such as Aioi Nissay Dowa, Allianz, AXA, Bridgestone, CNES, Generali, HERE, Kapsch, Liberty Mutual, Michelin, Octo Telematics, Pioneer, Qualcomm, Telit, Thales Alenia Space and Toyota.

- He assisted one of the world's largest **insurance groups** in designing its **telematics strategy & business plan across Europe;**
- **Led a global analysis of the market for cloud-based in-vehicle platforms**, involving interviews with automotive OEMs worldwide;
- **For one of the largest global car makers,** he defined the insurance telematics and fleet management **specifications of their future embedded device;**
- For a space agency, assessed the **market potential of autonomous vehicles** for the satellite industry;

Frederic performed a complete review of this report.

Thomas Hallauer, Research Director, London

BA, International Business, South Bank University, London

Thomas Hallauer has gained 15 years of strategy, research and marketing experience in the domain of telematics and location-based services from companies such as **Admiral, DriveFactor, Liberty Mutual, Michelin, Mobile Devices, Octo Telematics and Wunelli.**

He is expert at highlighting new trends, unearthing profitable niches and marketing new products and services notably in the automotive, motor insurance, LBS, navigation and positioning industries.

Before PTOLEMUS, Thomas held management responsibilities with **Mobile Devices**, a leading provider of telematics technology platform and devices and with **TU Automotive**.

Thomas is the lead author of the ETC Global Study, the most thorough review of the Electronic Toll Collection and Road Charging market published in May 2015.

Thomas also **reviewed and published the Connected Insurance Analytics Report and the UBI Global Study 2016,** interviewing dozens of insurance companies.

Thomas led the research, writing and publishing of this report.

Matthieu Noël, Manager, Paris

MS Automotive Engineering & Project Management, ESTACA, Paris and MS Marketing, HEC, Paris

Matthieu Noël has gained **6 years of consulting experience in the automotive sector** primarily helping car manufacturers such as **BMW, PSA Peugeot-Citroën, Renault-Nissan** and **Faurecia**.

Within PTOLEMUS, he has advised numerous clients such as **Admiral, Airbiquity, Allianz, Kapsch, Octo Telematics** or **Vodafone Automotive** in defining and implementing their strategy. He holds expert knowledge of domains such as connected vehicle data & analytics, OBD dongles, vehicle repair and maintenance, fleet telematics, fuel card services, ETC, UBI, autonomous vehicles, etc.

He led or participated in **more than 20 consulting assignments**, particularly in Usage-based Insurance (UBI), fleet management (FMS) and vehicle OBD data analytics for numerous applications such as vehicle remote diagnostics, eco-driving and driving behaviour analysis. He also recently contributed to the publication of the Insurance Telematics Global Study and Electronic Toll collection Global Study. He also regularly speaks at conferences.

Matthieu regularly speaks and moderates panels on automotive, mobility and telematics services at conferences. He recently presented the future of the UBI market at **Telematics India conference in Bangalore**.

Matthieu performed a complete review of this report.

Claire Elnécavé, Senior Expert, Brussels

MSc Management, Toulouse Management School

Claire Elnécavé has gained 12 years of experience for companies such as Accor, Arthur Andersen, Baloise Insurance, Baupost Group, Carrefour, CIC Securities, Coyote System, Pioneer, Sara Lee and Solvay.

She is expert at auditing and developing business models, financial statements, business plans, financial models and market models.

She built a 10-year forecast of the European telematics fleet management market for a $40 billion American hedge fund.

Claire also recently built the **5-year insurance telematics business model** of a leading European connected car services operator. She also contributed to the organisation of a series of strategic workshops on telematics for an insurance company and built its telematics business plan.

She also recently investigated the UBI analytics strategic landscape and built detailed profiles of 10 major suppliers including Lexis-Nexis, Octo Telematics, Willis, Towers Watson, Verisk Analytics, etc.

She is also **leading the creation of the Autonomous Club**, a think tank focused on industry and regulatory evolutions driven by the emergence of autonomous vehicles.

For this report, Claire contributed to our analysis of major AV technology suppliers.

Alberto Lodieu, Senior Consultant, Paris

MBA, HEC Paris - BSc Industrial Engineering, Instituto Tecnologico y de Estudios Superiores de Monterrey

Alberto has gained 7 years of experience in strategic and operations consulting, helping organisations such as **CNES, Danlaw, Europ Assistance, the European Commission and Liberty Mutual.** He has specialised in the **financial services and transport** industries in projects related to corporate and competitive strategy, operations excellence and business analytics.

Alberto has participated in more than 20 projects to help organisations identify, define and implement the initiatives needed to achieve or preserve their leadership position.

In his last 5 assignments, Alberto has helped multinational companies, willing to succeed in the connected vehicle market, to define their **global go-to market strategies**.

Before joining PTOLEMUS, Alberto worked for Deloitte Consulting in their strategy and operations practice. Additionally, he has participated as a strategic and financial advisor in investment projects both in **Europe and Latin America**.

For this report, Alberto analysed the evolution of the relationship between drivers and cars and the acceptance of AVs by customers.

Sahand Malek, Consultant, Brussels

PhD, Automotive Engineering, University of Bath, & MS, Mechanical Engineering, University of Birmingham

Sahand Malek has gained almost 5 years of experience in automotive research and development projects on vehicle On-Board Diagnostics (OBD), data management and analytics, Usage-Based Insurance (UBI) and Advanced Driving Assistance Systems (ADAS).

He notably conducted an extensive academic study on the effect of driving behaviour on fuel consumption and road safety that led to the development of various frameworks and post-processing methods to analyse driving data. He managed to identify, classify, and model driving behaviour differences from real-world data from fleet drivers.

He also gained extensive experience in **conducting projects that are using on-board diagnostics tools (OBD)**, portable emission measurement systems (PEMS) and location-based sensors.

He has in-depth knowledge about many aspects of traffic and transportation science, as well as automotive engineering. He has proficient statistical and technical knowledge, and he is capable of providing advice on both managerial and technical levels.

Sahand recently **led the writing of our recently published Connected Insurance Analytics Report.**

For this report, Sahand built our bottom-up market forecasts and scenarios of the ADAS and AV markets globally.

Philippe Brousse, Senior Business Analyst, Brussels

MSc Eng., ENSIMAG & MS Strategy ESSEC, Paris

Philippe has gained 3 years of experience in strategy and market research for companies such as **CGI Business Consulting, Danlaw, Europ Assistance, the European Commission, Kapsch, Octo Telematics and Safran Morpho.**

He has performed multiple assignments in the connected mobility domain such as:

- The definition of a global payment provider's connected services strategy for the consumer market,
- An assessment of the Benelux fleet telematics management market for a North American TSP,
- The evaluation of the EU fleet telematics management market for a $40 billion US hedge fund,

As part of our Connected Mobility Forecast, he conducted the analysis and 5-year forecasts of the markets for bCall, UBI, fleet management, and in-vehicle WiFi hotspots worldwide.

For this report, Philippe contributed to the building of our bottom-up market forecasts of the ADAS and AV markets globally.

Justin Hamilton, Senior Business Analyst, London

BA, Politics, Univ. of East Anglia and M.Litt. International Relations, University of St Andrews

Justin has more than 4 years of experience within the transportation, mobility and road user charging market. He conducts quantitative and qualitative analysis of global trends and developments in mobility, electronic road pricing and intelligent transport solutions.

Before joining PTOLEMUS, Justin launched Road User Charging Magazine and is frequently published in journals such as *Thinking Highways*, *Tolling Review* and *Tolltrans*.

His recent projects include:

- **A comprehensive ranking of global ETC service providers**, systems integrators and technology suppliers worldwide,
- For one of the world's largest roadside assistance companies, investigated **new digital assistance models** and analysed their breakthrough impact on the value chain,
- The writing of our UBI Global Study 2016, the reference research on the connected insurance market, quoted by *Fortune*, *Forbes*, the *Financial Times*, *Reuters*, *Corriere della Serra*, etc.
- A **global analysis of the car sharing, car pooling, car leasing and car rental markets** for our recently published Connected Mobility Forecast 2016.

For this report, Justin explored the relationship between autonomous cars and mobility and evaluated the factors driving the timeline of automation.

Yaron Steinfeld, Business Analyst, Paris

MSc Sustainable Development, HEC Paris and BBA, Business Administration, University of South California

Yaron Steinfeld has gained experience in strategy and market research for organisations such as Cleia, CNES, HERE, LafargeHolcim and Octo Telematics.

Yaron has worked on several connected mobility projects related to vehicle data, UBI, roadside assistance, car pooling.

For example he recently participated to the UBI market review of a major insurance telematics solution provider. He also participated to the global analysis of the market for cloud-based in-vehicle platforms, involving interviews with car makers worldwide.

Yaron brings a unique perspective to PTOLEMUS through his interest and experience related to smart cities. His focus is on analysing how technology merges with transportation to create solutions for better functioning, more liveable urban environments.

Finally, Yaron contributes to the research and analysis for our **quarterly quantitative dashboard of the global UBI market.**

For this report, Yaron led our analysis of the impact of ADAS and AV technologies on the number of accidents and their severity.

Matthew Cobbold, Business Analyst, London

MEng (Hons) in Civil and Environmental Engineering, Imperial College London

Matthew has gained 2 years of strategy and research experience for companies such as Strategy& (PWC group), Ernst & Young and WS Atkins.

He holds a strong experience in computational modelling and mathematical analysis.

Matthew has **performed several research and market modelling projects** for construction, pharmaceutical and telecommunication industries.

He recently participated to the commercial due diligence of a cyber security solution provider. Matthew conducted researches and interviewed experts to size the hardware security modules market.

For this report, Matthew contributed to our model of the impact of AVs on insurance claims and premiums.

FOREWORD

When discussing autonomous cars, Mary Barra, GM's CEO, stated: "**The auto industry will change more in the next 5 to 10 years than it has in the last 50**."

The most insightful portion of this quote is not necessarily the use of the word change, nor the timeline attached. Rather, it is the inclusion of the automotive industry as a whole.

Reflecting the way we have approached this report, **change will not be limited to just car manufacturers, suppliers or dealers.** Change will be wholesale. It will have an impact far beyond the great motor cities of Detroit, Wolfsburg, Aichi, Birmingham and Turin. The shock waves will be felt equally by financial districts, insurance hubs, political centres and technology clusters across the globe.

Today, vehicle automation is somewhat limited to Advanced Driver Assistance Systems (ADAS) such as automatic emergency braking and lane keeping assist. These level 2 autonomous features began appearing in cars many years ago and their incorporation in new models has steadily increased amid competition among OEMs and occasional regulatory mandates.

Yet, **despite their potential to reduce accidents, these features have been mostly ignored by insurers so far** and have had little effect on premiums.

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In the last 12 months, we have seen an acceleration in autonomous development, supported by a large number of ground-breaking announcements, deals and partnerships from all major players across the autonomous vehicle value chain, including:

- **Intel's $15 billion acquisition** of leading vision-sensing provider Mobileye;
- **GM's $1 billion acquisition** of the 40-person strong software and artificial intelligence developer Cruise Automation;
- **Ford's $1 billion investment** in unknown start-up ARGO-AI, accompanied by a joint $150 million investment in lidar manufacturer Velodyne and investment in Civil Maps;
- **Apple's $1 billion investment** in Chinese ride hailing platform Didi Chuxing;
- **Uber's $680 million acquisition** of self-driving start-up Otto;
- **Daimler, BMW and Audi's joint $3 billion acquisition** of HD map provider HERE;
- **Intel's acquisitions** of deep learning developer, Nervana Systems and vision processor Movidius;
- **Microsoft's partnerships** with Toyota, Renault Nissan and Volvo;
- Google's decision to spin-off and re-brand their self-driving car division **Waymo and the subsequent partnerships with Honda and Fiat Chrysler;**
- **Mobileye's** partnerships with GM, Intel, Wabco, BMW, Delphi and Volkswagen;
- **Nvidia's** emergence as a key supplier of deep learning and processing components to Tesla, Honda, Volvo, Audi, Daimler, BMW, VW and Baidu;
- **Allianz**' launch of insurance policies for semi-autonomous and driverless cars;
- The UK Government's proposed **Vehicle Technology and Aviation Bill**, which mandates insurance coverage for autonomous cars both when the drivers are in control and when they are not.

All are examples of different **players moving to ensure they are not let behind in the race to develop and deploy highly automated vehicles (HAVs)**. The scale of some of these transactions underlines the seriousness with which all stakeholders are approaching the issue. What was once though to be science fiction is likely to become a reality much sooner than most people are aware.

"Speeding, officer? You'll have to ask the self-driving car."

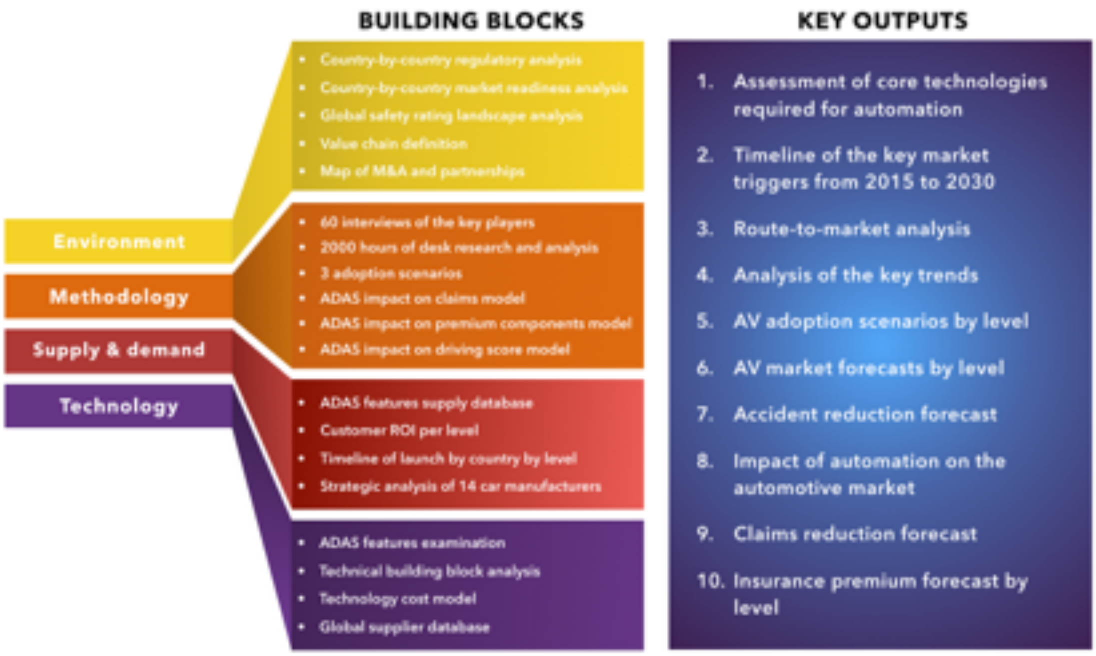
Car manufacturers are undoubtedly in the eye of the autonomous vehicle storm, but they are not alone. At each step of the way they are accompanied by **a growing ecosystem of players**, consisting of insurance companies, regulators, suppliers, mobility providers, investors, cities, telematics service providers and, of course, the drivers themselves.

With this in mind and reflecting on the magnitude of adjustment which will necessarily take place across numerous industries - many of which have enjoyed decades of stability - we felt the time was right to publish this report. The scope of this study reflects this, with 600 pages of crucial analysis covering the evolution and future of the technology and the risk management it will involve.

Crucially, **the report considers the implications all levels of automation will have on accident risks**. By leveraging our experience as global thought leaders in Usage-Based Insurance (UBI) and insurance analytics, we have considered the impact of ADAS (level 2), through to level 3 automation and finally fully autonomous and driverless (level 4) vehicles.

Using the building blocks outlined below, interviewing the marketplace and leveraging our skills in forecasting and analysis, we are confident we have constructed **the most comprehensive and insightful report on autonomous vehicles available today**.

The AV Global Study 2017: methodology and key outputs



Source: PTOLEMUS

This report further benefits from:

- 18 months of desk research in the connected mobility market,
- The insights from 90 consulting assignments on connected & autonomous driving;
- Interviews with 60 executives from across the automotive landscape,
- A review of worldwide mergers, acquisitions and strategic undertakings by applicable companies.

It has been a pleasure for us to write this report. We hope that you will enjoy reading it. If your company plays a role in this business and has not been mentioned in our report, please let us know so that we can update it in the coming months. Please send your comments to thomas@ptolemus.com.

Sincerely,

Frederic Bruneteau

Managing Director

EXECUTIVE SUMMARY

When will automation arrive?

- **By 2025, 100 million vehicles will be on the road with some form of advanced cruise control** in the US and Europe.
- **By 2030, there will be more cars on the road globally with ADAS than without**. Specifically, 370 million vehicles will have some automated features and 13 million will be highly autonomous.
- **Most OEMs will *not* launch a level 3 vehicle**, preferring to jump straight to level 4 to avoid re-engagement and liability issues.
- **Driverless (shared) cars will arrive on the market before level 4 (owned) cars** because they will be introduced in restricted areas first. OEMs will become mobility service providers as a means to retain the customer relationship and offset the risks of decreased car shipments.

Why?

New technologies

- OEMs will retain the control over **building the cars**, but technology companies such as Google, Uber and Intel could be those that build the intelligence behind them, including the **relationship with passengers**. Deep learning and AI is the core innovation ahead of sensors.
- **Positioning to the centimetre** will become a must. In urban environment, HD maps will have the edge in providing that level of accuracy. Elsewhere, high accuracy GNSS positioning will be required.
- **Adding level 3 assistance in vehicles will cost 80% more** than installing level 2 features - level 4 will be a further 360% more expensive!
- **The fall in lidar prices to below $100** will dramatically reduce the cost of level 4 systems from 2019 onwards.
- **79 GHz radar technology** will become popular thanks to miniaturisation and automatic hazard recognition.

New supply models

- **At level 4, customers will gain almost €1000 every year** thanks to time savings, increased productivity and lower running costs.
- Level 4 automation will shift the way OEMs market and sell vehicles. The car will become a **second office or living room.**

- **OEMs will become peer-to-peer car sharing platforms**, encouraging owners / lessees to share their cars to make them more affordable.
- Going further, **automation will blur the lines between ownership and sharing** when owners will share and then use other shared cars if their own is not available.

Regulation

- To avoid liabilities over re-engagement and unpredictable driver behaviours, OEMs will make **driver-facing cameras standard.** Thus for users, the loss of responsibility will come together with a **loss of privacy.**
- Unless shared, driverless vehicles could hurt cities and society due to increased traffic and lower tax income. **Regulations could forbid empty cars** to avoid this.
- City councils, regional and state regulators risk missing out entirely if they do not accelerate the pace of regulatory change. **Manufacturing and innovation will move where autonomous vehicles are road legal.**
- A precipitate market entry combined with lax regulation could be the perfect recipe to make people scared of autonomous cars. **"Ghost cars" could become as worrying as genetically modified food!**
- **Vehicle safety star rating systems** maintained by NCAP testing agencies will be one of the **most potent drivers of autonomous features**. The most advanced countries in that respect, namely Europe, the US and Japan, will benefit from them.
- **The first driverless cars will be electric.** Electrification and automation are likely to move in sync, promoted by cities. This will push governments to revisit the way they produce power in many countries such as Germany and the US. Nuclear, wind and solar energies are the most likely winners.

How will automation impact risks?

- **By 2030 almost 30,000 crashes could be avoided in the UK and Germany** thanks to ADAS and automation. **In the US, 630,000 collisions could be prevented!**
- Our models of ADAS impact on accidents and insurance claims losses & premiums show that **premiums could drop by over 40% in the US and 60% in Germany** if all vehicles become autonomous. When considering the penetration of L4 vehicles in these countries, the drop will be limited to 13% by 2030.
- **Level 2 ADAS will improve driver scores** by up to 15 percentage points and level 3 by 34 points.
- **AI will rapidly obtain better driving score than human drivers, forcing insurers to develop new risk pricing models**. Conditional automation and adaptive cruise control will require UBI data to price effectively.

- We expect that **product liability will not replace car insurance**. It will be integrated in the drivers' policy alongside third party liability (TPL) and own damage cover. Drivers will still claim for AV-involved accidents.
- **At Level 4, automation will reduce losses from crashes by a maximum of 88%**.
- In case of a frontal collision, ADAS alone will have the biggest impact on claims cost with a 30% reduction overall. However, **ADAS will improve a driver's risk profile but not his/her driver behaviour, making UBI increasingly relevant**.
- Cruise control and ADAS features do make driving much safer. **On average, level 2 ADAS can reduce the value of claims by 46%.** We expect innovative insurers to introduce ADAS and later AI-based insurance early to profit from the positive selection and accumulate relevant data sets.

How will automation impact the automotive ecosystem?

- Automation, combined with the continued growth of mobility services and higher cost of AVs, will fundamentally change the way cars are bought and sold, fostering **the emergence of a new 'buy-to-share' market**. Toyota and Ford have already begun the process in partnership with US platform Getaround.
- **Car sharing and ride hailing services will merge to become a single mobility solution** delivered via smartphones. OEMs are moving quickly to take control of this market.
- The OEMs leading the race to deliver level 4 autonomous cars are also the **market leaders in mobility services**, for example BMW and Daimler**.** By 2020, we expect all key mobility service operators to benefit from OEM investment or partnership.
- The race to deliver level 4 driverless cars will fuel **rapid consolidation of the mobility services market.**
- **Dealer and repair networks** will need to reinvent themselves to compensate for the decline in accidents, for example as AV charging stations.
- **Taxi and public transport operators, roadside assistance companies and automobile clubs** will all need to radically change their value proposition.
- **Road agencies / toll chargers** will need to move to a free flow payment model, which will require a migration of their complete charging and enforcement infrastructure to ETC (Electronic Toll Collection).

FOOD FOR THOUGHT

'What we've got will blow people's minds, it blows my mind …and it'll come sooner than people think'

Elon Musk
CEO, Tesla

"Anyone who focuses solely on the technology has not yet grasped how autonomous driving will change our society."

Dr Dieter Zetsche, Chairman, Daimler AG

"The technology for fully autonomous driving is not yet fully mature. We will also need a clear legal framework to accompany the introduction of this technology."

Harald Krueger, CEO, BMW

"Don't overhype automated driving: computers still have a perception issue."

Prof. John Leonard, MIT

"I bet in two years, it will be the norm that on the highway, you're not driving half the time or you'll be using driver assistants heavily."

Chris Dixon, General Partner, Andreessen Horowitz

John F. Kennedy

"Man is still the most extraordinary computer of all."

"The automotive future should not be left to Silicon Valley."

Matthias Müller, CEO, Volkswagen

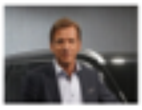
"We're thinking bigger than a single use case, bigger than a particular vehicle, bigger than a single business model.

What we are bringing to market is a self-driving technology platform."

John Krafcik, CEO, Waymo

"In the long term, the generalisation of autonomous vehicles means that 80 to 90% of the motor insurance business could disappear, along with claims management."

Pascal Demurger, CEO, MAIF Insurance



Håkan Samuelsson, CEO. Volvo Cars

"Volvo wants to remove the uncertainty of who would be responsible in the event of a crash.

At the moment it could be the manufacturer of the technology, the driver, a maker of a component in a car."

"You'll never own a car again. I have two and a half year old boys. They're not going to drive when they turn 18. They're going to have an autonomous car driving them around."

Peter Diamandis, Founder, XPRIZE Foundation

Representative of the German Federal Office for Motor Vehicles (KBA) discussing Tesla's *Copilot* function

"If the word beta-phase means an incomplete status of the software, the KBA would not authorise (such) a functionality."

"When the steam engine arrived, the horse wasn't just killed off, it became a hobby for enthusiasts.

And that's what will happen to cars, and I will continue to drive cars because I like driving cars."

Jeremy Clarkson, Broadcaster

"We don't want driverless to be the next GM food."

David Williams, Technical Director, AXA Insurance

"The autonomous age has dawned and Honda, like all automakers, is working to refine and advance this technology to achieve our goal for a collision-free society in the 2040 timeframe."

Frank Paluch, President, R&D Americas

"You can't be half-pregnant or partially pregnant and a car can't be partially autonomous."

Jochen Haab, Head of Active Safety, Mercedes Benz - discussing Tesla's Autopilot

James Dalton, Director of General Insurance Policy, ABI

The growth in features like automatic braking and lane assistance systems may give drivers a false sense of security that they can relax while their car looks after them.

Jen-Hyun Huang CEO Nvidia

"Developing a fully autonomous car is an end-to-end systems problem – from the in-car supercomputer, to AI algorithms, to an always-updated 3D map in the cloud"

Travis Kalanick, CEO, Uber

So if that's happening, what would happen if we weren't a part of that future? If we weren't part of the autonomy thing? Then the future passes us by basically, in a very expeditious and efficient way."

SCENARIO OF A NOT-SO-DISTANT FUTURE

The landmark court case of March 2023 changed the motor industry forever.

The **merged reality headset** now commonly used to handle the speed and behaviour of the autonomous car demonstrated how the vehicle's AI platform failed to prevent the death of its passenger.

Under pressure from the federal government and the customer protection lobby, the United States' National Highway Traffic Safety Administration introduced **pre-market approval** on all levels of automation. Individual state laws then followed what some European countries had already begun to implement. Namely, legislating that OEMs would be fully liable for any incidents and had to **share driving data with the vehicle owner** at will. Only the user could then choose whether to share it with a third party.

Yet, in effect, many OEMs had already forsaken the responsibility to handle each and every incident directly, **leasing to the arrival of service providers** whose role was to "secure" user's data while handling the - albeit rare - cases where a crash had taken place.

Insurance premiums for non-autonomous cars have skyrocketed, mainly to compensate for the huge cost of repairs. Most independent bodyshops began to lose out due to the proliferation of sensors with company-specific tuning methodologies.

Level 3 adaptive cruise control had become mandatory on certain motorways and insurers were investigating and penalising drivers if the switch was turned off too many times. This remained one area where insurers and OEMs managed to co-operate successfully.

Insurance brokers survived, as always, by promoting various **self-driving policies**, based on the number of minutes driven in non-autonomous mode. The basic 2000 min per month package was selling well at a price of $350 per year.

Specific road portions were also free to drive on, but often carried an involuntary excess which kept motor insurance mandatory. Comprehensive coverage included **glass and sensor repair**, hacking and theft protection, as well as maintenance delays. Software updates had become completely automatic and OEM-controlled.

Losses had fallen in line with the number of incidents, yet premiums remained stubbornly higher than expected. The value of the vehicles had increased significantly since the days of non-automation due to the continued additional cost and complexity of software and features. As a result, the already bullish mobility-as-a-service market, whereby **cars were either shared for a particular amount of time or hailed on-demand**, continued to grow. Hyper valuations attached to start-ups such as Uber, Didi Chuxing, Lyft and Grab had disappeared amid a concerted effort by each of the OEMs to seize a share of the most lucrative vehicle services market. Attempts by both Google and Apple to pre-install their own mobility service applications had been blocked by European Union on the grounds of anti competition.

The main saving grace for insurers had been the **thriving market for vehicle theft**. The tectonic shifts in patterns of vehicle ownership had left cars to bitterly fend for themselves amidst a burgeoning market for security bypass software produced and sold by hackers halfway across the globe.

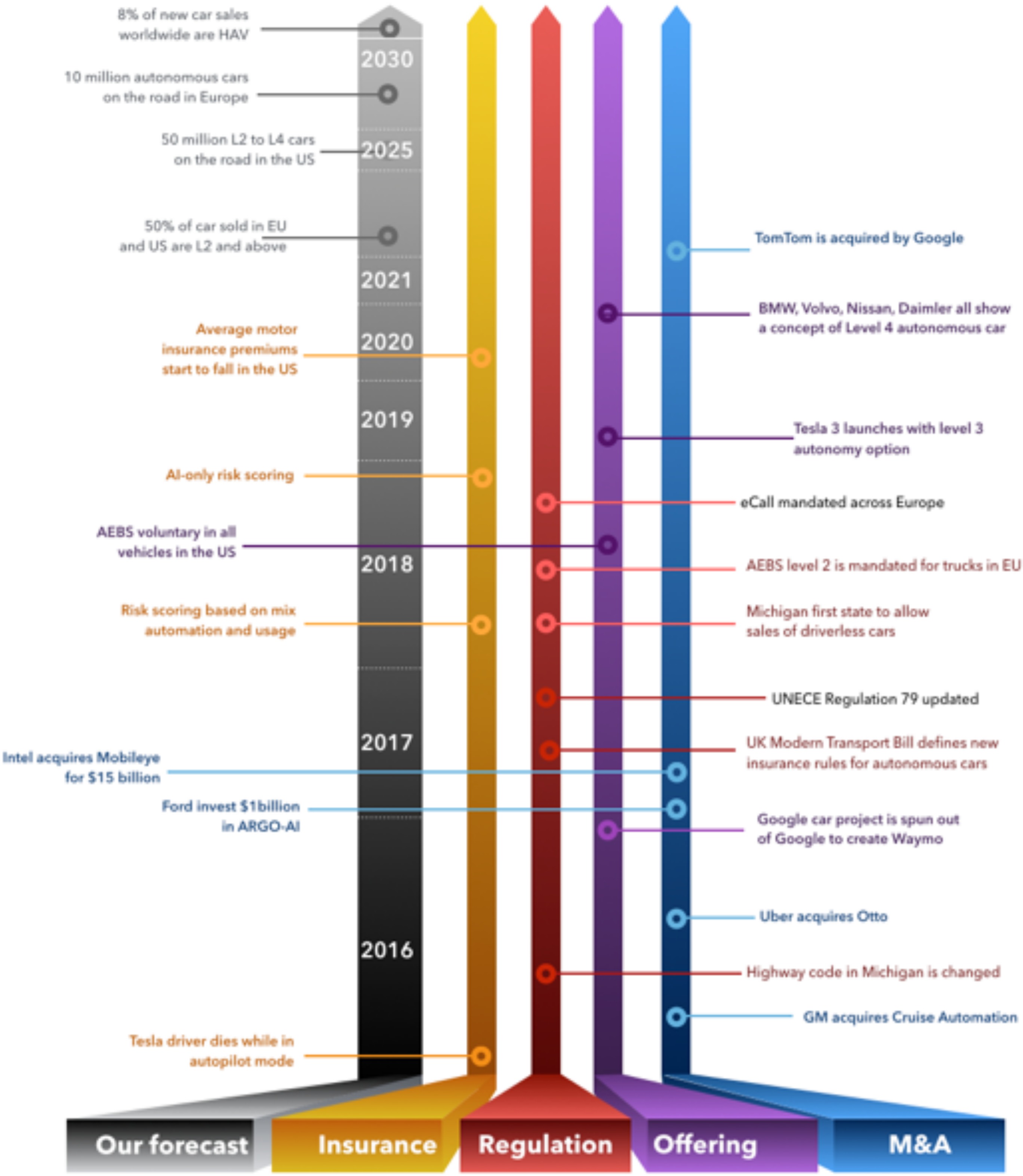
Regions including South America, Eastern Europe, Russia and the Middle East had finally begun to see autonomous cars on their roads, albeit with liability still resolutely with the driver.

The big event of the year was of course the latest announcement from Tesla - who had just moved ahead of Suzuki and into the **top 10 car makers in the world** - who were launching trials of their fully electric airborne drone, in partnership with Uber.

The future never stops accelerating.

Airbus* Pop.Up *concept flying taxi, shown at the 2017 Geneva Motor Show, could be on sale within 7-10 years

A TIMELINE FOR AUTOMATION



The rush to prepare

Connected vehicles are rapidly becoming a reality in Europe and multiple benefits are expected to arise from their deployment: increased road safety and traffic efficiency as well as reduced CO_2 emissions.

The market will evolve fast: global revenues from connected vehicle services are expected to grow from €100 billion in 2015 to nearly €350 billion in 2020.

The gradual moves towards **highly automated vehicles** will only accelerate this trend. Expected to be launched commercially in Europe in 2023, fully autonomous vehicles could reach a global base of 33 million by 2030.

These two evolutions could bring about a new industrial revolution and immense social progress. However, it is still unclear how this transition will take place and how the different players will be impacted.

On the regulatory side, legislators have just started to prepare for the future. Member States are asking EU institutions to **provide a clear regulatory framework to develop connected and automated vehicles by 2019**. As Günther Öttinger, the former Commissioner for Digital issues puts it: "We need to move forward many significant issues before these vehicles are commonplace on our roads". These will include liability, data ownership, driving rules, connectivity, cybersecurity, etc.

The discussion on automated driving and connected cars, both at a technical and at an institutional level, **has started**. The automotive and the telecommunication sectors, which are well established and leading European industries, have already been vocal in the debate. However these discussions have hardly spread much **beyond vertical silos** and/or at **national level**.

A European horizontal platform for interaction to define the challenges is missing. **This is why PTOLEMUS and LYSIOS are creating The Autonomous Club.**

The Club aims to involve all stakeholders participating in or impacted by the autonomous vehicles including **automotive OEMs** and **their suppliers, insurance** and **rental** companies, **private and public transport operators** together with **infrastructure builders**, **city councils** and of course the **European institutions**.

How will the stakeholders connect?

The Autonomous Club, is a European forum for discussion, brainstorming and exchange, which will gather participants from various horizons.

Two guiding principles will steer its activities:

- **A balance between private and institutional speakers** in order to have a deep and wide understanding of the issues at stake,
- Openness to all stakeholders in the connected and automated vehicle ecosystems.

The forum organises bi-monthly events that will take different forms; **breakfast meetings**, **half-day workshops** or **networking dinners**. At each event, at least one institutional and one industry representative speak on the chosen issue.

These events will be opened to all stakeholders **by invitation only**. **Club members** will benefit from additional services.

What are the objectives of the club?

1- To identify the key strategic and business issues facing the sector.

A robust analysis of the **economic, technical, social and strategic** aspects of the development of connected and automated vehicles is crucial to detect the issues.

Some of them may already have been discussed but the complexity of connected and automated vehicles and the fast-paced environment they evolve in, requires stakeholders to constantly anticipate the emergence of new challenges.

2- To identify potential regulatory needs. Once current and upcoming issues have been spelled out, stakeholders will have a clearer picture of the gaps legislation should, or should not fill. Hence **an open and inclusive discussion** involving all stakeholders and issues, could be even more fruitful.

3- To build upon this analysis to take action and make their voice heard at the European institutional level.

The clubs priority is therefore to foster networking and relationship building between all key stakeholders.

What are the benefits to The Autonomous Club members?

The spirit of The Autonomous Club is an open association of **corporate members** to inform and brainstorm on strategic issues around the vehicle automation and connectivity.

We expect to have an impact on key decision makers in the regulatory and business domains (European Commission, European Parliament, Brussels-based trade associations such as ACEA, CLEPA, FIGIEFA, etc.).

TAC full members benefits	TAC open group members benefits
• Free participation of up to **5 company executives** to each event organised by TAC; • Access to the **presentations** made during the events; • Access to the **directory of members** including contact details of representatives; • Access to the **event participants details**; • The ability to **contribute to TAC's event programme**; • Participation to internal debates; • **Contribution** to possible papers issued by TAC; • Typically the **possibility to speak** at one of the events during the year.	• Access to each event upon invitation; • Access to the public **presentations** made during the events; • Participation to internal debates.

Examples of the themes discussed by the Club's members include:

- The evolution of European regulations affecting the autonomous car market,
- The control over and access to automated car data from the business, technical, cybersecurity and privacy perspectives,
- Identifying the forthcoming European research needs early on,
- The impact of automated vehicles on urban mobility. How will these vehicles interact with each other? How will they affect traffic, roads building, road maintenance, public transport and parking lots?

Initial event programme

The Club will run a flexible programme of key topics based on the bi-monthly cycle of events.

While most of the events are planned in **Brussels**, if the needs is shared, TAC will be able to accommodate some of the meetings in other European capitals.

Date	Theme	
22nd June 2017	**The impacts of automated vehicles on the automotive ecosystem**	
	TAC Members: Free	TAC open group: €50
September 2017	**The necessary framework to handle liability at EU level**	
	TAC Members: Free	TAC open group: €90
October 2017	**The impact of AVs on urban mobility and cities**	
	TAC Members: Free	TAC open group: €90
December 2017	**Who will control connected & autonomous vehicle data?**	
	TAC Members: Free	TAC open group: €90
February 2018	**Should Europe mandate V2V?**	
	TAC Members: Free	TAC open group: €90
April 2018	**Autonomous trucks changing the logistics landscape**	
	TAC Members: Free	TAC open group: €90

A more detailed version of the meeting programmes will be available shortly

About The Autonomous Club (TAC)

TAC is a Europe-wide think tank set up by **LYSIOS** and **PTOLEMUS Consulting Group**.

PTOLEMUS is the first international strategy consulting & research firm entirely focused on connected & autonomous vehicles. Established in 9 countries, it helps all stakeholders in the mobility ecosystem define and implement their strategy.

LYSIOS is a public affairs firm established in Brussels and Paris.

To join the club, please contact TAC@PTOLEMUS.com

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LIST OF PROFILED COMPANIES

In this report, we assessed 23 companies looking at their core strategy on automation, their active and planned tests and trials, the technology used, the relevant market activities (such as partnership)

They have then been ranked using 6 criteria: ADAS development, testing programmes, published patents, relevant market activities, R&D spending and strategic focus.

Profiles, assessments, sub-criteria definitions and ranking per criteria can be found in Section III. 4

OEMs		Technology suppliers
BMW	navya	BOSCH
DAIMLER	PSA GROUPE	Continental
FCA FIAT CHRYSLER AUTOMOBILES	RENAULT NISSAN	DELPHI
Ford	TESLA	HARMAN
GM	TOYOTA	MOBILEYE
HONDA The Power of Dreams	VOLKSWAGEN GROUP	NVIDIA
HYUNDAI	VOLVO	Valeo
JAGUAR LAND ROVER	WAYMO Alphabet Google	

LIST OF COMPANIES MENTIONED IN THE STUDY

During the last 18 months, **PTOLEMUS research team interviewed 60 executives in organisations** such as Allianz, Continental, Daimler, GM, Harman, HERE, Mobileye, PSA, TomTom, Valeo, Volkswagen, Volvo, Swiss Re, Toyota, etc.

We list below **all 250 companies mentioned in the Autonomous Vehicle Global Study**.

Company	Type	Company	Type
Association of British Insurers	Insurer	**Lyft**	Mobility Services Provider
Advanced Scientific Concepts	Automotive supplier	**Magna Electronics**	Automotive supplier
Ageas	Insurer	**Magneti Marelli**	Automotive supplier
Aisin AW	Tier-1 supplier	**Mahindra**	OEM
Alfa Romeo	OEM	**Maserati**	OEM
Allianz	Insurer	**Maven**	Mobility Services Provider
Alphabet	Software/AI developer	**Maybach**	OEM
Alpine	Automotive supplier	**Mazda**	OEM
Amazon	Software/AI developer	**Mercedes Benz**	OEM
AND Products	Mapping provider	**Metromile**	Insurer
Apple	Software/AI developer	**Micron**	Automotive supplier
ARGO AI	Software/AI developer	**Microsoft**	Software/AI developer
ARUP	Research/ standards institute	**MINES Paris Tech**	Research/standards institute
Athlon	Mobility Services provider	**Mini**	OEM
Atkins	Research/ standards institute	**Mitsubishi Electric Automotive Europe**	Automotive supplier
ATZuche	Mobility Services Provider	**Mitsubishi Motors**	OEM

Company	Type	Company	Type
Audatex	Software developer	**Mobileye**	Autonomous systems developer
Audi	OEM	**MOIA**	Mobility Services Provider
Autoglass	Breakdown services	**Moovel**	Mobility Services Provider
Autoliv	Automotive supplier	**Movidius**	Automotive supplier
Autonavi	Mapping provider	**Movimento**	Software developer
Autonomos	Software/AI developer	**Multicity**	Mobility Services Provider
Autotalks	Automotive supplier	**Munich RE, NA**	Insurer
AXA	Insurer	**MyTaxi**	Mobility Services Provider
BAE Systems	Automotive supplier	**NASA**	Software/AI developer
Baidu	Software/AI developer	**National Highway Traffic Safety Administration**	Regulator/ Government agencies
Belron International ltd	Breakdown services provider	**Nauto**	Automotive supplier
Blacklane	Mobility Services Provider	**NavInfo**	Mapping provider
BMW Group	OEM	**Navya**	OEM
Bolloré	Mobility Services Provider	**Nexteer**	Automotive supplier
Bosch	Automotive supplier	**Nicigo ADAS**	Automotive supplier
BYD Co.	Automotive supplier	**Nirenberg Neuroscience**	Software/AI developer
Capgemini	Software developer	**nuTonomy**	Software/AI developer
Car2Go	Mobility Services Provider	**NVIDIA**	Automotive supplier
Careco	Mobility Services Provider	**NXP**	Automotive supplier
Careem	Mobility Services Provider	**O2**	Telecom infrastructure
Carglass	Breakdown services	**Octo Telematics**	Telematics service provider

Company	Type	Company	Type
CATAPULT UK	Research/standards institute	**Ola**	Mobility Services Provider
Centro Tecnologico de l'Automocion Galicia (CTAG)	Research/ standards institute	**Opel**	OEM
CESVIMAP	Research/ standards institute	**Otto**	Software/AI developer
Chariot	Mobility Services Provider	**Ottomatika**	Software/AI developer
Chrysler	OEM	**OuiCar**	Mobility Services Provider
Cisco	Telecom infrastructure	**Oxbotica**	Autonomous systems developer
Cite lib	Mobility Services Provider	**Panasonic**	Automotive supplier
Civil Maps	Mapping provider	**Paravan Industry**	Autonomous systems developer
Cloud made	Software/AI developer	**Pearl Auto**	Autonomous systems developer
Co-op	Insurer	**Peiker**	Automotive supplier
Cohda Wireless	Automotive supplier	**Peloton**	Autonomous systems developer
Comma.ai	Autonomous systems developer	**Pepperl+Fuchs**	Automotive supplier
Communauto l'autonomie	Mobility Services Provider	**Perrone Robotics**	Autonomous systems developer
Continental	Automotive supplier	**Pilot Automotive**	Autonomous systems developer
Control-Tec	Software developer	**Pioneer**	Automotive supplier
Cruise Automation	Software/AI developer	**PPZuche**	Mobility Services Provider
CTAG	Research/standards institute	**PSA Peugeot Citroen**	OEM
CVTA	Automotive trade association	**QNX**	Software developer
DAF Trucks	OEM	**Qualcomm**	Automotive supplier
Daimler AG	OEM	**Quanergy Systems**	Automotive supplier
Daimler Insurance Services	Insurer	**RAC**	Breakdown services

Company	Type	Company	Type
Delphi	Automotive supplier	**RDM Group**	Automotive supplier
DeNA	Software/AI developer	**ReachNow**	Mobility Services Provider
DENSO	Automotive supplier	**Renault Nissan Alliance**	OEM
DfT	Regulator/ Government agencies	**Renesas Electronics Corporation**	Automotive supplier
Didi Chuxing	Mobility Services Provider	**Ridecell**	Mobility Services Provider
Dodge	OEM	**RideScout**	Mobility Services Provider
Drive.ai	Autonomous systems developer	**Rolls Royce**	OEM
DriveNow	Mobility Services Provider	**RSA**	Insurer
Drivy	Mobility Services Provider	**Safe drive systems**	Automotive supplier
Elektrobit	Mapping provider	**Safran**	Research/standards institute
Engineering and Physical Sciences Research Council	Research/standards institute	**SAIC (UK)**	Automotive supplier
Enjoy	Mobility Services Provider	**SAIPS**	Software/AI developer
Ericsson	Telecom infrastructure	**Samsung**	Automotive supplier
Ertico	Research/standards institute	**Savari**	Automotive supplier
Euro NCAP	Research/standards institute	**Seeo**	Automotive supplier
European Commission	Regulator/ Government agencies	**Siemens**	Automotive supplier
Facebook	Software/AI developer	**Sixt SE**	Mobility Services Provider
Faraday Future	OEM	**Skoda**	OEM
Farmers Insurance	Insurer	**Smart**	OEM
Fiat Chrysler Automobiles	OEM	**SMMT**	Automotive trade association
First Direct	Mobility Services Provider	**SoftBank**	Software/AI developer

Company	Type	Company	Type
Folksam	Insurer	**STMicroelectronics**	Automotive supplier
Ford	OEM	**Subaru**	OEM
Ford Carsharing	Mobility Services Provider	**Sunfleet**	Mobility Services Provider
Free2Move	Mobility Services Provider	**Suzuki**	OEM
Freescale	Automotive supplier	**SWECO**	Research/ standards institute
Fujitsu Ltd.	Automotive supplier	**Swiss Reinsurance Company Ltd**	Insurer
Garmin	Mapping provider	**Takata Corporation**	Automotive supplier
General Motors	OEM	**Tata**	OEM
Getaround	Mobility Services Provider	**Tesla**	OEM
Gett	Mobility Services Provider	**Texas Instruments**	Automotive supplier
Global NCAP	Research/standards institute	**Thatcham Research**	Research/standards institute
GoDrive	Mobility Services Provider	**The Alliance for Transportation Innovation**	Automotive trade association
Google	Software/AI developer	**The Floow**	Telematics service provider
Grab	Mobility Services Provider	**Times Car Plus**	Mobility Services Provider
Greenwheels	Mobility Services Provider	**TomTom**	Mapping provider
HailO	Mobility Services Provider	**TorcRobotics**	Autonomous systems developer
Harman International	Automotive supplier	**Toshiba**	Automotive supplier
Hella KGaA Hueck & Co	Automotive supplier	**Towersec**	Software developer
HERE	Mapping provider	**Toyota**	OEM
Highways England	Regulator/ Government agency	**TriQuint**	Automotive supplier
Hitachi Automotive systems	Automotive supplier	**TRL**	Research/standards institute

Company	Type	Company	Type
Honda	OEM	**TRW**	Automotive supplier
Horiba Mira	OEM	**Tula**	Automotive supplier
Horizon Robotic	Autonomous systems developer	**Turo**	Mobility Services Provider
Huawei	Telecom infrastructure	**Uber**	Mobility Services Provider
Hyundai	OEM	**Uisee**	Software developer
Ibeo automotive	Automotive supplier	**UNECE**	Regulator/ Government agencies
IBM	Software developer	**Valeo**	Automotive supplier
IBM Watson	Software/AI developer	**Vedecom**	Research/standards institute
If P&C Insurance	Insurer	**Velodyne**	Automotive supplier
Infineon	Automotive supplier	**Visteon**	Automotive supplier
Infiniti	OEM	**Vodafone**	Telecom infrastructure
InMotion	Mobility Services Provider	**Volkswagen**	OEM
Insurance Europe	Insurer	**Volvo Car Group**	OEM
Insurance Institute for Highway Safety	Research/standards institute	**Voxx international**	Automotive supplier
Intel	Automotive supplier	**Wabco**	Automotive supplier
Jaguar Land Rover	OEM	**WaiveCar**	Mobility Services Provider
Jeep	OEM	**Waymo**	OEM
Karhoo	Mobility Services Provider	**Yandex**	Software/AI developer
Koolicar	Mobility Services Provider	**Zenrin**	Mapping provider
leddartech	Automotive supplier	**ZF Lenksysteme**	Automotive supplier
LG Electronics	Automotive supplier	**ZF TRW**	Automotive supplier

Company	Type	Company	Type
Lincoln	OEM	**Zipcar**	Mobility Services Provider
Local Motors	OEM	**Zoomcar**	Mobility Services Provider
		Zurich Insurance Company	Insurer

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Disclosure

The recommendations and opinions expressed in this study reflect PTOLEMUS' independent and objective views. However, PTOLEMUS cannot provide any guarantee as to the accuracy of the information provided or the reliability of its analyses and forecasts.

INTERVIEWS

François Guichard

UN Secretary Vehicle Active Safety - Focal Point ITS
United Nations Economic Commission for Europe (UNECE)

The UNECE defines the safety requirements for type approval in new vehicles. Can you please tell us how the update of the UN Regulation No. 79 is progressing?

Experts on active safety and advanced driver assistance systems under the World Forum for harmonisation of vehicle regulations have just adopted technical provisions as a first step towards the introduction of self-steering systems.

The group defined 5 categories of automation corresponding to the functionalities that the vehicle will be able to perform and adopted performance requirements for the first 2 levels of automation defined by SAE International.

These **relate to systems that, under specific driving circumstances, will take over the control of the vehicle under the permanent supervision of the driver**, such as self-parking functions and Lane Keeping Assist Systems (e.g. when the car will take corrective measures if it detects that it is about to cross a lane accidentally).

They also entail removing the current limitation of automatic steering functions to driving conditions below 10 km/h contained in UN Regulation No. 79. Once adopted by the World Forum at one of its forthcoming meetings, these provisions will be integrated into UN vehicle Regulation No. 79

Many vehicles on the road are already capable of much more automation. How did a car like the Tesla S receive approval?

Tesla was type approved by one of the EU member States, and from there it got *de facto* an approval valid for the rest of Europe. This was done on the basis of requirements that are now updated and clarified.

How does the regulation regulate Lane Keeping Systems?

With these new provisions, lane keeping on highway is not only defined as the capability to stay between two markings on the lane, it also defines what happen if the car does not manage to do that anymore.

Two situations then: transition demand, i.e. asking the driver to take control followed by a **minimum risk manoeuvre** if needed.

In some cases, this could be as simple as stopping on your own lane for systems with lower capacity.

Some experts on the subject said they would prefer to have the car stop on the lane safely than try to change lane in an unsafe manner.

This is a definition of the technical requirements for a more advanced ACC system that includes ACC and lane keeping (so both directions are controlled).

Administratively, this first set of requirements will be submitted to the world forum for endorsement later this year. The entry into force will be a few months later.

Will this address automated driving globally?

More than 50 countries follow the world forum decisions and use them to define the rules on homologation. They are bound by the requirements, other countries are referring to it, meaning they incorporate them into their own national regulations.

Are the USA going to apply these requirements?

The USA rely solely on national regulations and standards applied to the automotive sector but also collaborate at WP.29: the World Forum has a second regulatory framework applied by the USA, China, India, EU, Korea Japan and other countries.

The Forum develops within this framework some kind of meta-regulations whereby the country agrees on requirements that they have to transpose into their national laws. This differs from the framework for UN Regulation. Once R79 is ratified, it will be transposed into law automatically.

Global technical regulation (GTR), within the second framework, are not directly applicable, a second step is needed.

The US government did not influence the working group on R79. It was mostly pushed by Japan, Germany and Korea which where backed by the UK, France and Spain.

The US industry however was very active.

All the work is done under the R79 umbrella, which is dealing with steering and we are adding elements related to braking.

Therefore, we might work on a new regulation in the near future.

Why introducing braking elements?

The systems have to be good enough to detect moving "targets" but also standing objects on the highway.

One of the collisions we saw in the recent past was the result of the sensor not recognising whether the standing object in front was on the road or part of the infrastructure.

This is a conversation we have had with AEB for trucks and buses. One of the challenges was to avoid false alarms because of standing objects. There is a need to regulate this because it is a real problem that could discredit the technology in the eyes of consumers.

We will regulate AEB for passenger cars and light vehicles within the next 2 years. That doesn't mean we will mandate it but member States such as the US, Japan etc. will be able to mandate AEB on the basis of our regulation.

In addition, the braking requirements will be there to make sure that in case of an emergency, the vehicle is able to cope with it and

address it safely. This might also be addressed by requirements for functions working similarly to AEB.

As part of the technical and safety requirement, are you going to include a reliability requirement? We know from testing agencies such as Thatcham that AEBS can avoid 20% of the front-facing collisions. That suggests it misses 80%.

Not to my knowledge because we cannot quantify that.

There are reasonable practical limitations into what can be done by authorities before a product can be put on the market.

The industry does test and verify reliability through a very wide range of tests, winter / summer, multiple locations, something that most of OEMs are doing over a few years per model. This is not what authorities are responsible for doing.

Besides the regulation, and perhaps more importantly, are market acceptance and market demand. If the systems are costly and not functional, they will be baldly received and not sold. **Market demand is sometimes a more efficient tool than regulation.**

If a regulation suggests the functions have to be, let's say, 75% reliable (only), that could impact the competition and some companies would stop trying to do better.

We saw that one of the problems that led to incidents is the natural human expectation that if the car rides the same route multiple times, it will learn to drive it better. While technology providers are clearly working on this to be the case one day, do you believe "learning" will become part of the safety requirements?

To learn from each other, cars would need to be connected.

Today the connectivity in vehicles is mainly for entertainment. There is no link between the vehicle motion and its connectivity.

If there were, we would immediately start having serious cyber security risks to manage. Until we have a better understanding of how to manage these risks, I expect we won't have the opportunity to use connectivity to steer a vehicle.

To date, in the development phase, data may be collected for testing purposes but this is only for the technical testing process, not from a regulatory perspective.

If you have big data used in and coming from the vehicle, it will be very difficult to secure it. Cyber security and software safety are important considerations.

Do we have a cybersecurity problem today?

I don't see a crisis to date. We do have example of what can be done for hacking but they come mostly from universities and researchers alerting about potential crisis.

The point is that, as long as there is no connection between the brain of the car and the web (or whatever is outside of the car), we don't have too many potential problems. **The bigger problem starts once we**

connect the driving function of the vehicle to the web.

We heard from NHTSA recently. They published a very detailed safety requirement list and defined the Operating Design Domain concept and required OEMs to send them a letter identifying the capabilities of each of their cars from Level 2 onwards.

Is NHTSA going in the type-approval direction?

In the USA, the safety standards designed by NHTSA are in the self-certification framework. This differs from the emissions requirements, with the EPA, being much closer to the European system. The Policy paper issued by NHTSA on AV has a holistic approach.

At UNECE, we focused more specifically on technical requirements in Regulation No. 79, so there are certainly elements of this policy that can inspire our work e.g. on over-the-air update issues.

Also, it is worth noting that depending on manufacturers, a new vehicle type-approval may take around 3 months. Personally, I have never experienced type approval to be a problematic factor delaying market introduction.

NHTSA published guidelines only. How can you work in a self-certification market if you don't have very strict standards defined?

If you look at the standards defined by the Federal Motor Vehicle Safety Standards (FMVSS), they are very stringent, sometimes more than the UN ones. We always work with a third party, so there is a possibility to discuss things and their interpretations.

When OEMs work on the basis of self-certification there is no third party. They need to perform the test according to the regulation.

As of today, nobody really knows holistically how and when AV will work, so it is impossible to define very strict and precise standards for the purpose of self-certification.

What is remarkable is that NHTSA looked at pragmatic options, such as the possibility of a third party testing.

NHTSA is insisting throughout the document on data transfer and transparency. This is a core issue for the insurance sector. Will R79 bring answers regarding what data is shared and how?

What we try to do is to deliver technical tools being useful for further concerns, such as the determination of responsibilities in case of collision involving these technologies.

We are drafting requirements for some of the information to be kept on the system. This suggests a sort of black box where a set of data is securely stored for a certain time.

That dataset is defined to understand what led to the incident and possibly to help reconstruct it, including:

- If the automated system was on or off,
- If the driver was interfering,
- If the driver was attentive, in case an attention detection system was available.

The collection of the data will need to take into consideration cybersecurity risks as well as data protection (impacting privacy).

Do you expect the black box data to be accessed wirelessly or manually, as Electronic Data Recorders are in the US?

I suspect that in order to follow the data protection regulation and to protect the driver, it will be preferable that the **wireless transmission of the data is forbidden**, which is a point that is advocated by the FIA.

We know OEMs are all looking at being able to upgrade their product over the air during their life on the road. How will this affect the homologation rules?

At this stage we have not got a precise answer yet on this item. However work is in progress since March 2016.

If you look at the US guideline, you will also see some suggestions regarding software upgrades – specifically that they need to be communicated to NHTSA in time.

If you look at what is happening already today, you'll find that some ECUs may encounter problems and that they can be flashed at the dealership. Software

Core activities of the WP9

updates already exist and are already part of the processes if tackled as "retrofit".

So what remaining regulation to have a L3 vehicle legally on the market will need to be passed once the national highway code has been changed?

The borderline between level 2 and level 3 is vague. In our technical work at UNECE, we prefer to work on clear technical requirements for categories of systems corresponding to certain use cases.

At level 2, the driver has the obligation to monitor the situation outside and inside the car. At level 3, the driver only has the obligation to monitor the proper working of the system. Not the environment, as long as the system doesn't request to do so. Again, this is quite vague and could be subject to interpretation.

We do work on integrating the SAE levels in our regulatory framework. But when we talk about the requirements, we move away from them for more clarity.

The regulatory process for such technologies is ongoing and we expect that the full specifications will be adopted by the working group by September 17.

In terms of the traffic rules, there are complications that need to be looked at. They include the enforcement by the police related to the secondary task.

If the driver is in a level 3 vehicle and using his smartphone, what would be expected from a policeman? How will they react?

We can guess that the UN body looking at driving rules internationally and the Vienna convention will come up with a standard rule to solve this problem.

Interview conducted by Thomas Hallauer in November 2016

David Williams

Technical Director

AXA Insurance UK

Last year Allianz France came up with a 25% discount on premiums for cars equipped with at least two ADAS functions. Do you think that the insurance sector has a responsibility to promote ADAS adoption by offering discounts?

I think we need to use the various sources of information to enable us to be much more precise, rather than offering discounts.

We know that Automated Emergency Braking (AEB) reduces road accidents by an estimated 15% and injuries by 18%, and we reflect that in our pricing.

But some studies indicate a variable performance in sensors and braking systems at different speeds. It might be that the Bosch system fitted on the VW Golf works better than the Volvo system in high speed situations, but the Volvo AEB works better in low speed situations.

So, as insurers, in order to build our pricing models, we need to understand precisely what ADAS components are fitted and take into account what we know about people's driving behaviour.

A lot of manufacturers make ADAS components available as add-ons, and **we're already speaking to the government about the need for some sort of database that we can tap into** – possibly with the vehicle registration number linked to the vehicle identification number (VIN) which in turn looks at what kit is

fitted so we can reflect that in our pricing.

So yes, **we absolutely need to be encouraging the adoption of ADAS, and the best way to do that is to reflect it in reduced premiums.**

Do you think that premiums will first go up in line with the increased cost of the vehicles fitted with these features, or down because of their impact on claims?

We are already seeing a substantial impact in the cost of damage claims. **Over the last 3 years, I think the UK market figure is a 25% increase**, which is well ahead of inflation.

The claims that have increased are due more to own damage than third party damage claims.

Most of the expensive kit tends to be fitted to the front of these vehicles, which is where the damage is more likely to occur if you crash into something.

So, yes, there will be an inflationary impact on claims. But you've got to remember that while the increase has been 25% in terms of damage claims costs over the past 3 years, the technology will be reducing costs going forward.

AEB is already showing a 15% reduction in accidents and an 18% reduction in injury claims.

But the premiums are also based on the value of the vehicle. At level 4, will that value increase dramatically?

Most claims are small claims, so unless you're talking about an exceptional vehicle, the overall value isn't as important in terms of our pricing as the cost of repairing the individual model type.

Since we are unable to establish which vehicles are fitted with expensive kit if they were supplied as options, maybe some people are getting away with it.

But the most costly claims are for injuries. We would much rather smash up a driver assistance sensor than a pedestrian. So we are very much of the opinion that the overall outcome will be lower insurance premiums, even just with ADAS.

When automated cars outnumber "ordinary" cars, how will this affect the premiums on vehicles that are not ADAS-equipped?

I think there is a lot of paranoia around that. You have to consider the dynamics of road accidents.

If your car was the last manual vehicle on the road, statistically you would still be less likely to have an accident than you would now, because all the other cars would be autonomous with safety features to avoid a collision with you.

So, while you wouldn't benefit from the discount, overall you'd end up with a lower premium.

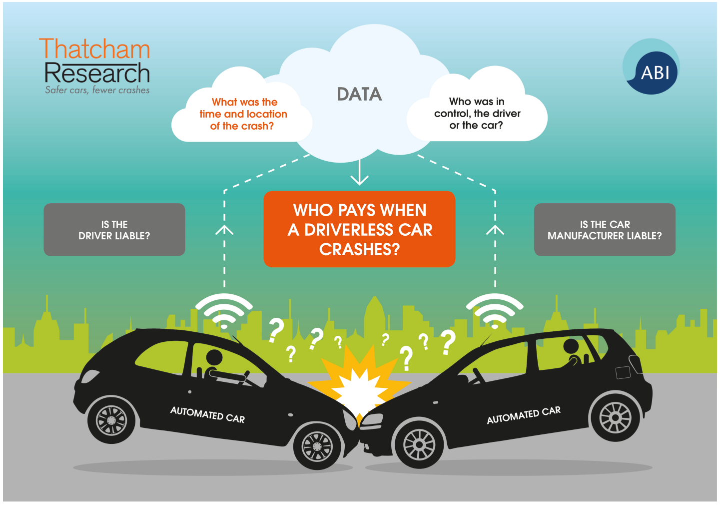
How do you expect the insurance rules to evolve in order to protect drivers and riders of autonomous vehicles?

Within the Association of British Insurers (ABI), **we formed the Autonomous Driving Insurance Group (ADIG)**, of which I am the Chairman.

When we started discussing these issues, we were of the opinion that there would be fewer motor insurance policies and a huge increase in product liability premiums, which would be with the manufacturers. Then we got into the practicalities of who's going to be responsible.

In the UK, the **Road Traffic Act (RTA)** is not there to help motor manufacturers or to sell insurance premiums; it is there to protect road users. So if you then start with the mindset of protecting road users and making things simple for them, you end up thinking about a slightly different model.

13 companies are involved in the ADIG



Determining liability will be a challenge for insurers

I genuinely expect this to be reflected in the **Modern Transport Bill** when it comes out at the beginning of the year – that the government will extend the existing RTA regulations to make sure that other road users have that same protection. They don't want a situation where somebody involved in a road accident has to establish which insurance regime applies or maybe spend 3 years arguing against the OEM's most expensive lawyers!

Instead, **every vehicle on the road** – whether conventional, manual with a driver, autonomous with an optional driver or autonomous and driverless **– will be required to be covered by an insurance policy, and there will be a liability imposed on the insurer in respect to any accident involving the vehicle when in autonomous mode**.

Now, the benefit of that is that anyone involved in a road accident will simply go to his insurer who will do the usual investigations and pay the claim, whether it's for vehicle damage or personal injury.

This does not leave the motor manufacturers completely off the hook. In fact there is a strong argument that we should be encouraging them to make their vehicles safer.

The last thing the insurance sector wants to suggest is that manufacturers can reduce deaths on the road by 90%, but that they will be sued to the fullest extent of the law for the remaining 10%!

So would a taxi company need to have an extra policy?

The ABI has not focused on taxis, but there will be a requirement for a motor insurance policy, whether the vehicle belongs to a taxi company or a car sharing group of individuals.

Will that extra policy be an additional cost for the driverless taxi owner?

Technically yes, but with fewer accidents happening, motor insurance premiums are going to be cheaper anyway, and even lower for driverless vehicles.

The other aspect is: everything costs money! Nobody absorbs costs; they are passed onto the customer. **So the issue is where best to place them**.

When we are talking about specific elements of risk in terms of accident and repair and injury costs, then insurance is a good place to put it.

The government will agree, because we have a highly competitive market and therefore those costs are kept to an absolute minimum. If we introduce other elements into the mix, they might get talked up and cost the end-customer even more.

Across Europe we also have a variety of insurance regulations and rules. Do you think we're better placed to create something a bit more uniform?

I think so. I have some Brexit-related concerns, although most of the vehicle regulations are through the UNECE rather than Europe per se. But when you look at the people put in charge of the various committees, I worry that we might get less say in the matter.

I also think that, if you look at UNECE, most of the regulations that currently apply to driver assistance are being looked at to apply to autonomous vehicles. Regulation 79 refers to steering, which is ridiculously inappropriate for automation but **it's the best we can find**, and it take years to change.

We've already had meetings with an insurance organisation in Germany and we're setting up meetings with one in France, in **an effort to get UNECE – whether it's regulation 79 or something else – to do things more quickly**.

The UK will publish the Modern Transport Bill in early 2017, which will be something people can either critique or ignore, and it would be useful if something similar could be enacted across Europe.

Why do you think regulation 79 is inappropriate, and what do you think they should do instead?

I think **we need to start with a whole new regulation**.

In an autonomous vehicle, it is so much more than just steering; it's acceleration, it's braking. I think they are doing their best within an existing framework, but it was not designed for true driver assistance or autonomous vehicles.

That's why there is this obsession with the period of time you can take your hands off the wheel.

I think they need to come up with something more all-encompassing. But, since it takes ages to get something changed, maybe they're being pragmatic in using an existing regulation.

In cases where you are able to recover costs from the manufacturer, not only will you need information about the vehicle and its equipment, but also information about the accident.

In that context, what type of data is needed and how do you think insurers will access it?

Playing the devil's advocate, we don't have that information now and we're still able to deal with claims, so it's not the end of the world. However, the absence of that information raises a number of issues.

Ignoring the improvements in customer service that you could provide if you had that data, you'd be able to deal with the claim instantly; you would know everything, because these vehicles are computers on wheels.

Consider a situation where a vehicle has autonomous functionality that may or may not have been switched on. There will likely be some dispute, with motor manufacturers saying it's the driver's fault and the driver saying the car was in full autonomous mode and it did something weird.

It's just wrong that the only entity with access to that information is one of the defendants.

But the Modern Transport Bill will reflect the need for some information. We've had discussions with motor manufacturers, and **the large German motor manufacturers have very strict data privacy rules, regulations and standards, and therefore they don't want to share any information at all**.

However, I think they're going to have to. I think the Modern Transport Bill will start talking about the **need for some form of event data recorder,** and then we can start discussions about how granular the information needs to be and how we will get it.

Meanwhile, my understanding is that there's a bit of a compromise on the part of the German OEMs, saying that in terms of a specific event when something goes wrong, they're happy to share *certain* information – not everything.

However, they would prefer that some form of independent third party receives this information on everybody's behalf, due to concerns about data security. Imagine the potential risk if 60 insurers in the UK all asked Mercedes for data to be transmitted online.

I also think the **granularity of the data is going to be up for debate**. We had a meeting about that with the German Insurance Association (GDV), and ended up with a list of the absolute minimum things that we need, such as whether the vehicle was in autonomous mode or not. So I think we would at least get that, but we don't know if it will be direct from the OEM or via a third party. If it's a third party, who's going to set it up and how much is that going to cost?

Another thing we're discussing is the **potential to provide a better claims service by obtaining more data following an accident**.

Now, that might be a bit of a lifeline for telematics providers. Effectively, you don't need aftermarket telematics anymore because the vehicles themselves are computers on wheels, but if motor manufacturers say they're not going to release information, then maybe there's an alternative industry where telematics providers link into the vehicle's telemetry or just record things independently and then send the information to the insurer.

If that business model stacks up, then it could work, particularly as the cost of technology falls.

I believe that the **driving data belongs to the customer, and therefore should be made available to us with the customer's permission.**

How important is the re-engagement issue for the insurance sector, where a vehicle asks the driver to take back control and the driver does not do so?

In the UK, we are looking into the accelerating development of driverless cars or autonomous vehicles.

The **Venturer consortium** is currently conducting tests specifically regarding the handover.

The reason they're looking at it is because we have asked them to.

We – the insurer, partner of the Venturer consortium – are particularly concerned about it, as is the government.

So you and I can have an opinion now, but in a 12-month time, we'll have an informed opinion. Discussions with UNECE on Regulation 79 raised the issue of hands off the wheel for a maximum of 30 seconds; then it changed to 3 minutes, now it is back to 30 seconds, so it's all over the shop!

What we are describing, though, is not Level 4 or 5. If a vehicle ever requires you to take control, it is not autonomous; it is driver assistance. And yes, I do think this will be clarified in the Highway Code. **Some of the adverts you see on the television present a Level 2 system as almost a Level 4. It's shocking, and I think there will be prosecutions in the future** with regard to the marketing of driver assistance functionalities.

If something goes wrong in an autonomous vehicle it will tell you and it will deal with it. It will be able to turn off a motorway, come to a stop, park itself safely, etc.

If it doesn't, if it ever requires you to take control, then it is driver assistance only, and therefore I think the Highway Code in the UK will require the driver to be paying attention, and if there is an accident, it will be the driver's fault.

Look at the Tesla marketing – wonderful technology – but very, very clear regarding their accountability, as in, "If there is an accident, we do not expect to be held responsible. It is driver assistance; we're making your journey safer, we're helping you, but you have to constantly and effectively be able to take control if required."

So there is no re-engagement issue?

No, not with autonomous vehicles. **Anybody talking about re-engagement is talking about driver assistance**. And it's really important for us to understand. Because the worst situation would be if people were able to sell vehicles described as autonomous, but if something goes wrong you've got 10 seconds to take control. That's like putting an offensive weapon on the road; that's not safe, that's terrible.

While we expect automation and ADAS to result in fewer accidents, will the complexity in pricing and claims management actually increase the costs in the insurance market? What about the IT, data science involved in dealing with new data, could that actually increase the cost of motor insurance?

If this technology reduces accidents by 80%, we don't think there'll be an 80% reduction in premiums. It is like the cost of repairs; there will be elements that have a sort of near-negative counter-effect that will drive premiums up. But overall, we still think it will be substantially cheaper.

You have to remember the way that we're proposing this – that the conventional motor insurance market deals with claims in the first instance – continues to drive the highly competitive nature of the market. You have to find a way to deal with higher IT costs effectively, because your competitors will and they will be able to offer cheaper premiums.

So yes, there will be additional costs, but they will be on substantially lower – and less costly from an injury perspective – claims, and therefore **overall, premiums will still be massively lower**.

Is it fair to suggest that insurers will have to invest a lot more in IT, data science, actuarial and other costs separate from claims costs?

Yes, but we're doing that already. Getting decent data scientists in the London insurance market at the current time is incredibly difficult, because everybody wants one.

So while there will be more data, I think technology will move along - machine learning, for instance, artificial intelligence.

We've already discussed this with IBM Watson, and, just using machine learning, you can do the work of 10 or 20 actuaries much quicker.

So initially we will need to invest more, but, as with any new development, the costs will come down over a period of time.

What would you say are the biggest dangers and what should we do to avoid AVs becoming the new GM food?

First of all we need to make sure that, when they are on the road, the insurance regime and mechanism is simple and familiar. So again, our proposal that insurers deal with claims rather than people having to sue a motor company themselves will help in terms of public acceptance and confidence.

We also need to ensure that these vehicles and features are tested properly and that they are absolutely safe before they are allowed on the road.

We will be able to talk about the number of hours and miles that have been clocked up in these test environments, using simulation technology as well.

A lot of people are concerned about the Tesla approach, which is beta testing really innovative software on public roads.

I think we will also see connected autonomous vehicles suddenly appearing in the commercial vehicle space, where there is a massive business benefit.

Initially, when people see 38-ton articulated vehicles hurtling down motorways without drivers, they will be worried, but they will get used to them.

However, we can't pretend that there won't be any accidents. But we will need to be honest and open about the cause of those accidents and what's going to be done to ensure it doesn't happen again.

And again, if we could have some of that data that is being captured, that will be very useful.

Interview conducted by Thomas Hallauer in November 2016

Anders Eugensson

Director of Governmental Affairs
Volvo Car Corporation

What is Volvo's roadmap in terms of automation and what are the key milestones?

The starting point for us is the easier part of the road – motorways and A-roads, roads that are clearly **defined with the easiest context we can find**, with neat separations and one-way traffic in all the lanes. We start without intersections, cyclists or pedestrians - unless they step out of their cars.

In parallel with this, we work on **autonomous parking.** This is a low speed scenario, close to the parking garage or in the garage itself.

Both starting points will be expanded gradually. For highway driving, we will add more complicated scenarios step by step, such as intersections and roundabouts. The parking scenario will be gradually expanded to move further away from you or from your parking garage. So if you live in a building, the car can stop at the entrance where you can unload your shopping and then go and park itself.

Another example is at the airport, where you could leave the car in a dedicated space; it would park itself and come back when you return. It also means that those parking garages can have **lower ceilings and thinner slots** since nobody needs to get into and out of their vehicle when it's in the parking bay.

In Sweden, we talk a lot about densification of populated areas. If you live in a residential area, parking takes up living space. Imagine that cars are parked outside the residential area, shielded from the building and the highway. The car could then come to the residence on demand, at a low speed. During the short trip, it would stop as soon as it senses a problem. You would need Cloud Connect as a back up, so if the vehicle does not understand or know how to react to a situation, it would flash and call a dedicated control centre. A person would then be able to activate the camera in the car and identify any issues.

These two developments are the slowest, and they will merge **perhaps 15-20 years from now**, when we'll have cars doing everything everywhere. We will then be closer to cars on demand, ride sharing and mobility on demand.

It sounds far fetched, but the technology level necessary to make this scenario happen is fairly achievable. The difficult part is how to set aside a section of the parking space for autonomous vehicles. We will need mixed parking, and need to find ways to make this workable in places like Heathrow Airport.

In Sweden, the city of Gothenburg owns a number of parking spaces, and they are talking about creating an open area for autonomous parking. The technology is not that difficult, so **those first steps will be possible by 2021-2022** when we will launch the first levels of autonomous vehicles.

incidents in Sweden as well as Germany, and we also work together with a US federal agency. We look at the crash history and try to determine which of those are applicable to any section of the road in different scenarios. Then we look at other scenarios that were not captured in those databases and we add them.

Based on this work, we train our algorithms in simulation to see how they would react. We also simulate traffic flow and human behaviour in these experiments.

A huge learning process was involved in the mapping and cloud connectivity. **In effect, we have been running basic level automation there since 2014** – with Volvo engineers behind the wheel ready to take control. **They have been instrumental in exploring the infrastructure and the way the cars interacted with other drivers.**

Volvo's **DriveMe** ***scheme is the most ambitious pilot programme by an OEM***

What about the trials in Gothenburg and London? When will they start?

The Gothenburg trial is where we do a lot of the basic research on risk management, i.e. where we ensure the car manages all the risk scenarios. This is **not done on the road itself but through simulations**. We have a huge database of crashes compiled from

We identify which events the machine driver could or could not deal with until we believe the system is ready. **Then we look at the new types of crashes that could be generated by autonomous driving** – avoiding old crashes scenarios – and of course ensure that we avoid them.

This research produced the cars that we will start trialling in March 2017 in Gothenburg, but also in London in Q2 and then in China, and later in a fourth location.

These cars – while driven by engineers – will be autonomous with a lot of redundancies, but we will continue to add redundancy throughout the testing process. However, we will choose very carefully the road where these vehicles will be tested.

In the London trials, will you drive into the city centre or stick to one-way and single lane traffic?

In London, it will be on the M and A roads coming into London from the West first, but we will stop before the first intersection or roundabout – not because the autonomous car cannot handle such intersections, but because other road users could cross a red light and hit it. We need to work on ways to ensure there is no car coming at high speed that could crash into our car.

Uber's autonomous research is based on Volvo's platform, but the autonomous system is not provided.

But that is the risk any other car driver takes every day. How is that different for an autonomous vehicle?

Yes, but with better sensors, the car could determine and anticipate the behaviour of a car coming towards it. We plan to install sensors that will enable us to know that in the future.

So **the sensible way to do things is to plan a cautious approach, ensuring we can prevent such an accident before putting the car into a situation where it could take place.**

We also need to teach the car to look for an escape route if an accident is predicted. To do that, we need HD maps to understand the situation the car is in very precisely, and be in a position to determine the best option to avoid the incident.

How are the cars and the trials methodology different between London and the work with Uber in the US?

We have provided Uber with a platform with built-in redundancies. They have cars made to order with double systems for everything important in the operation of the vehicle, such as braking or direction assist. We don't do any development for Uber when it comes to the dashboard or the autonomous system.

The vehicles that we will bring to the US will be identical to the ones in Gothenburg and London.

Do you think we will see improved ACC features before we see high automation? Or will Volvo keep a clear gap between driving assistance features and automation?

It is, of course, tempting to make cruise control so good that the driver thinks it is autonomous and starts performing secondary tasks. **In Europe, it is also a regulatory issue, and we have the UN Regulation 79 that requires drivers to have their hands on the steering wheel every 30 seconds.** So we cannot take away the hands contact detection.

However, the ACSF requirement will soon be in place, and after that we could reach a level where the hands-on detection is off. If that were the case, we would then need to ensure the driver is not doing something that prevents him from assuming control again in time.

We won't launch a car at level 3; all the systems at level 2 require the driver's attention. The cruise control can be more stable, convenient and comfortable, but we need to always ensure the driver is reminded to stay alert before we come to Level 4.

At the stage of level 2 cruise control, do you think you will need to put in place behaviour/face recognition technology in order to monitor the level of attention you are describing?

We have not made the decision yet. It is one solution, but some secondary tasks could still be allowed so we would need to adapt to countries' regulations. Also, there are tasks that the driver can do alongside driving or being alert during cruise control, and **we need some kind of monitoring system** to identify that.

That said, such monitoring and the complexity attached to it suggests a camera will be in use. Is there any other way?

Before we identify behaviour, we can first optimise the warning and the assistance system for the drivers. Steering wheel movement is one solution, and we are using this in our cars.

But I agree that **the best solution is to look at the driver status** and check if he has fallen asleep, for example.

Before putting the autonomous cars on the market, you have described the progressive and careful process by which you are testing the system. There is another school of thought that is to ask customers to do the testing and then update the vehicle software with incremental levels of automation. What is your take on that?

A lot of things are wrong with that approach, but the main thing is that it doesn't work.

If you put thousands of cars on the road and nothing really bad happens to them, then it is impossible to collect the crash data needed to teach the system. I have been driving for 40 years and have never had a crash – not because I am a particularly good driver, but because I have never encountered that specific risk.

Yet that specific type of risk or crash exists and may happen in one or five years.

We are saying that we will not launch the cars onto the market until we are sure that we are able to react to any type of risk scenario.

Also, we want to make sure that, if there is any doubt and the car "is unsure" about what to do, it is able to stop safely.

We don't want the car to learn after it's too late and another car has crashed because we did not identify a scenario. **Learning on the road is not our way; our way is to learn beforehand.**

Is testing dependent on city-based exemption today, and for how long? Are we going to be in a situation where the technology is ready but vehicles are barred from using automation in certain cities, countries or states?

Yes, probably. I have just had a meeting with the UNECE and they are trying their best to sort everything out, but there are many different opinions. Some governments are not on board in ways that others are, because of lack of knowledge or because they do not see safety being taken care of in the same way as others.

If that happens, we won't be asking for city-wide

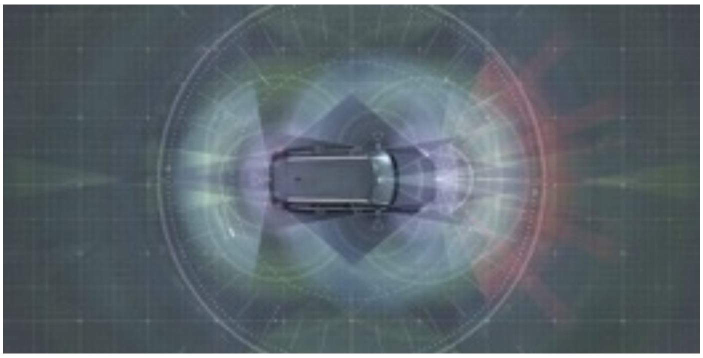
exemption. There are 3 ways to go about it:

- Get full type approval, which gives us the okay in most countries.
- Get a national exemption, meaning we have to approach each country individually.
- Get an exemption from the EU instead of type approval, this is also called article 20, based on new tech on its way to be regulated. Still, one country could say no to that, so we would be allowed to launch only in countries that approved it.

As part of the exemption, do you expect to have to demonstrate that the vehicle is visibly autonomous? The enforcement authorities will need to be able to recognise automation, but other drivers are better off not noticing.

Correct. We plan to do some trials and research to understand how drivers will react when they see someone at the wheel reading a newspaper. In Gothenburg, we have already seen patterns of behaviour where other drivers have tried to challenge the autonomous car by pushing or braking in front of it.

Clearly, **the police need to be aware and able to recognise when a vehicle is in autonomous mode.** We are in the process of discussing with them how this is going to play out.



Volvo's platform will include combined radar and camera, laser scanner, trifocal camera, long range radar, ultrasonic sensors

You mentioned that the trials would also take place in China. How will you manage the severe lack of HD maps there and the government's resistance to change on that front?

The Chinese government is very concerned about this. We are trying to say the map we use is not only geographic, it is more based on features that the car can identify.

So we created maps with the layers that each sensor recognises. We have one map for the LiDAR, one for radar, and one for the camera, but these need to be linked to the topographic features of the environment. We are trying to make maps that will fit in with their concerns and expectations.

In the rest of the world, do you need the map to be ready at the time of vehicle testing as well as market launch, or do you expect the cars will be able to build or complete the map as they go?

We can do the trials without the map being ready; we can use the road features and markings instead. For market launch, we have to have the cloud-based 3D maps ready.

Is technology still a barrier? What are you using today, how is it changing and what is critically missing?

In our production cars today, we use short- and long-range radars, one forward camera, small radars in the rearview mirrors, ultrasonic sensors on the bumpers and cross-function alert cameras (under the side mirrors) looking to the sides.

Regarding location, if the HD map is available at the level we want, we don't need anything else. Lane

markings are the default minimum the system will require for sideways positioning.

In China, where we might not get either, we will need something else to position the car.

In terms of connectivity, the car would work without it, but would struggle because the map is cloud-based and constantly updated with, for instance, road works information. **The basic map is in the car, but the 3D map requires connectivity.** Whilst we can drive with only the basic map and can use dead reckoning for a while if connectivity is bad, we require 3G connectivity or better to ensure the full safety of the vehicle.

This is affecting positioning as well as tactical decision making; assessing the risk before entering a situation. The map allows to us to ascertain the situation 200 metres ahead, so the aim is to never get in the "trolley dilemma", not to solve it.

We think we know what we will need in the future, but we're constantly testing. **Ultimately, we want the added cost of automation to be way under €10,000.** The price to the customer will vary depending on the timing and the availability.

In terms of use case, do you believe the first HAV will be shared or privately owned?

I think the first cars will be owned by normal customers because they are going to look like any other cars, but these will be people that are tired of sitting in traffic and wish they could use that time to check email or make phone calls. Gradually, as we have more vehicles in more places, this is when we get into the peer-to-peer sharing model.

Don't you think this will increase traffic and create lots of empty journeys?

Remember that our starting point with automation is not to go from A to B. Our starting point is to drive yourself until you reach a certified road where you can switch the autonomous function on.

Going back home alone will be the next step. The first level for us means you need to drive the complicated part of the journey as well as the start and end part of the journey.

Isn't the ability to drive from A to B in a defined area with defined conditions, such as weather, without the need for a driver the definition of level 4? What you are describing is level 3 autonomy.

No, this is level 4. The difference is that at level 3, the driver is the fall back if something stops working. At level 4, there are no fallbacks required from the driver. The difference is bigger than you may think, because it means having all the redundancies like parallel computers, parallel cabling, double braking, control, steering – everything backed up.

You talked about having very precise and complete risk assessment of any potential situation and the need to avoid them before the car gets near them. Doesn't that put you in a favourable position to become the insurer of that vehicle, giving your customers cheaper premiums?

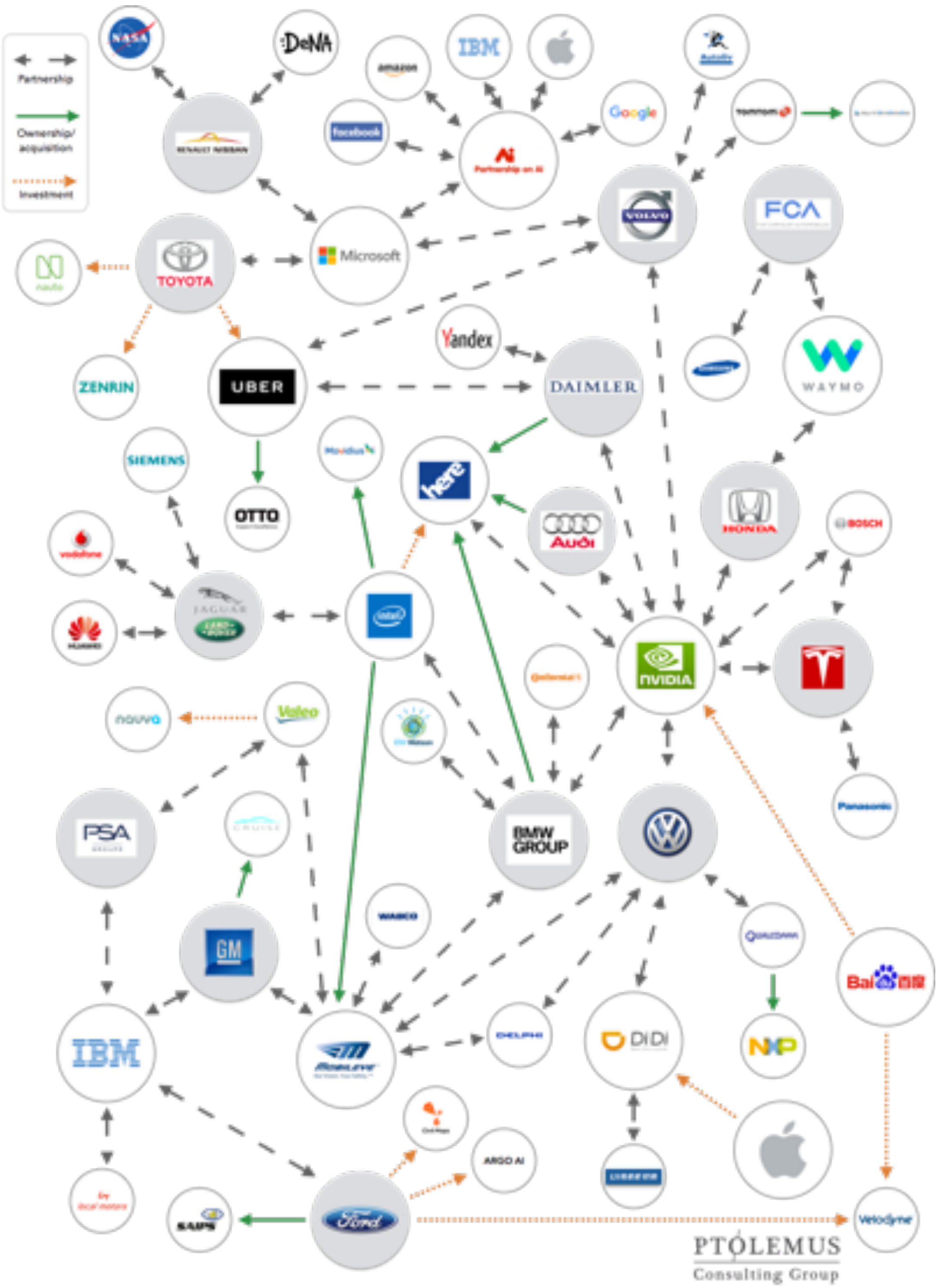
We are analysing this but have not made any decision. It is, of course, a possibility. These cars will not cause a crash. We could even do it using a reinsurer, but it is too early to say.

We know that the cars equipped with ADAS today are involved in fewer incidents and therefore less repair costs are attached to them. **Yet insurers keep the premium very high on those cars. So we are in discussion with insurers to change that.**

Interview conducted by Thomas Hallauer in March 2017

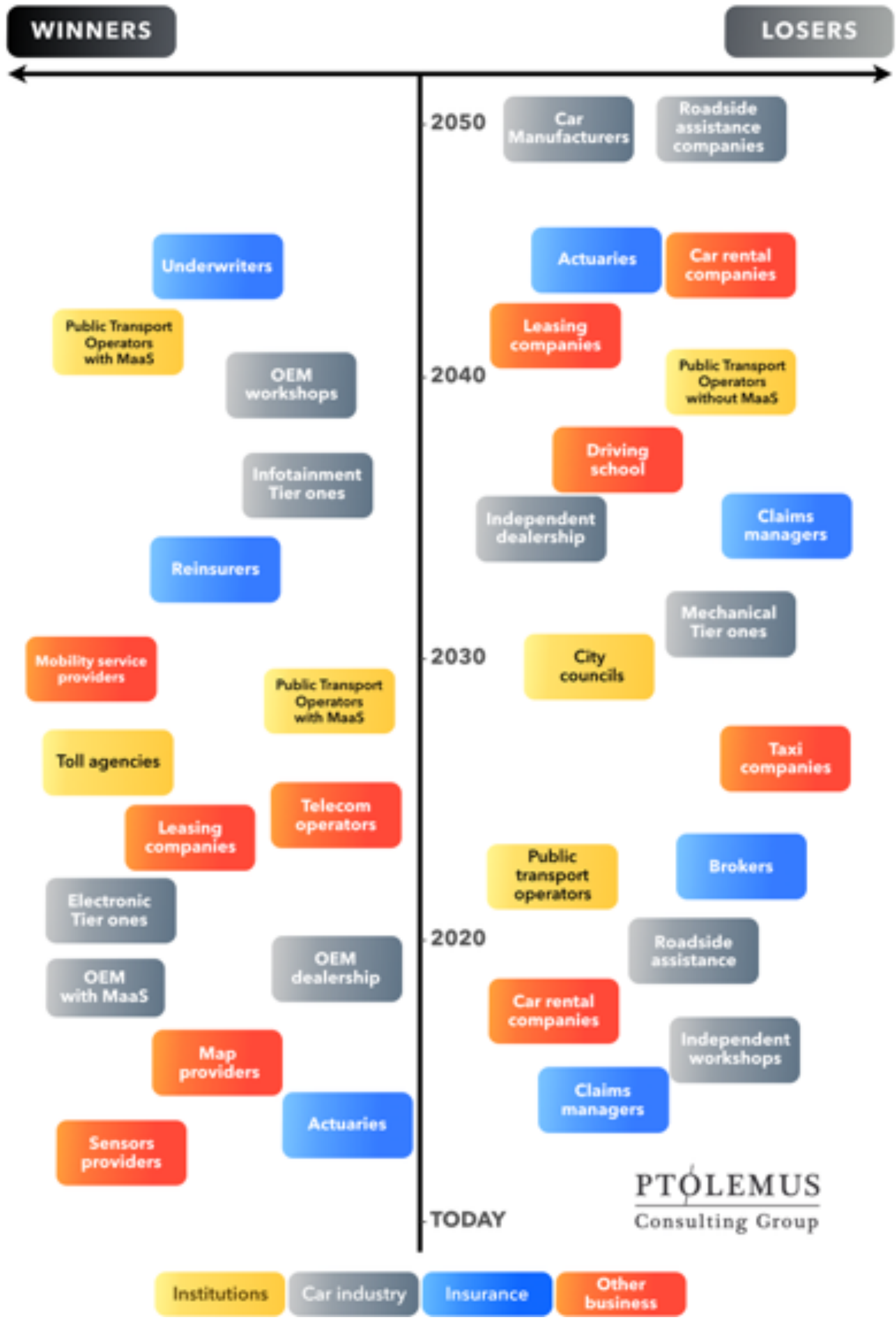
THE 2 SIDES OF THE AUTONOMOUS CAR COIN

Fig 0.1: Key partnerships, investments and acquisitions across the autonomous car value chain



Source: PTOLEMUS

Fig 0.2: Future winners and losers as autonomous vehicles come to market



Source: PTOLEMUS

I. THE KEY BENEFITS & CHALLENGES OF ADAS

1. What are ADAS and autonomous functions?

A. The 4 human cognitive processes

To drive, until now that is, we have used **4 types of cognitive processes**.

1) We sense the road environment ourselves; watching, listening (smelling) or feeling what is around us. These are the basic human functions necessary to **understand** the road environment in which driving is done and to **predict** how it will affect the activity of driving,

2) We sense the **contextual input** required to drive. Again watching, listening and feeling the information from the vehicle. This includes **the required activities around driving the vehicle as well as the external information** we use to operate the vehicle, such as map information or dashboard control. It can also include alerts (like the smell of fuel) as well as distraction - radio, children at the back etc.,

3) The **management and processing of the inputs** above. Once the environment and contextual data is sensed, the brain needs to determine what action is required - if at all - as well as it level of urgency,

4) Finally, the **execution of the action**. This is the process of acting on the vehicle to perform actions such as to accelerate, brake, steer and change gear.

ADAS is first about assisting and later, replacing these processes with automated ones.

To **sense the road environment**, a number of sensor technologies can be used including, radar, lidar (laser-based radars), camera and ultrasound. Generally speaking, carmakers seem to have settled on a combination of radar, lidar and camera technology, supported by 3-D and high-definition mapping. Ford and Chinese internet giant Baidu (who are also testing their own level 4 car) have even gone as far as investing millions of dollars in leading lidar manufacturer Velodyne. Tesla, on the other hand, has spurned the use of lidar, preferring to rely on a combination of camera and radar hardware.

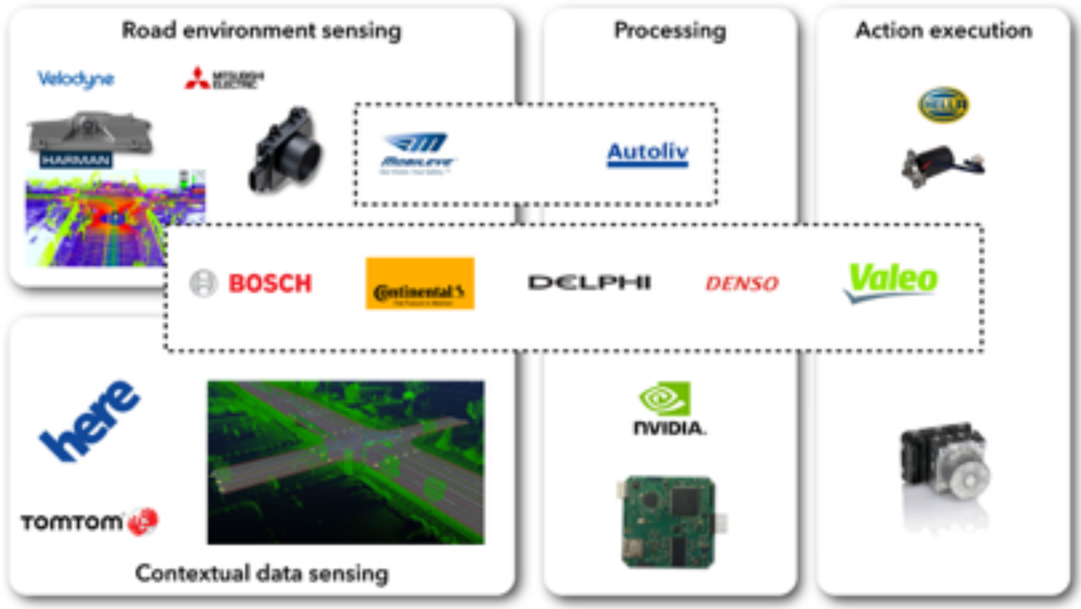
To **sense contextual information**, ADAS merges car sensor data with other types of information such as time of day, high definition mapping and in the future with information from the infrastructure or other cars.

The **core processing** is then conducted by processors and micro controllers using artificial intelligence (AI), advanced analytics and machine to machine communication.

Finally the **execution** is handled directly by the engine control unit (ECU) attached to the gearbox, braking systems, steering, suspension and electric as well as the non-driving related actuators.

Below, we have illustrated these 4 processes, the devices and the companies involved in the research and development of these technologies. We will look at the 4 processes and the technical requirements in much more details in Section IV.

Fig 1.1: New technologies assist or substitute human capabilities



Source: PTOLEMUS

B. The 4 steps of ADAS evolution

Today's ADAS solutions can be classified in 4 areas of progressive influence over the 4 cognitive processes.

- **Improvements:** the technologies provide additional road environment and contextual data to the one perceived by the driver however they don't suggest or take actions. Examples include:
  - Rear visibility cameras
  - Night vision with added screen on the dashboard
  - Understanding of the distance to a fixed object through proximity sensor
- **Alerts:** as the sensors process road and contextual data, triggers can be chosen to suggest specific driver action, or alerts over potential dangers. Examples of such applications include:
  - Forward collision warning

  - Pedestrian detection
  - Parking aid

- **Assists**: the triggers are now used to take over part of the driving process and supplement driver actions when the system judges it is necessary. Examples include:
  - Braking assistance: where the brakes are engaged fully by the ADAS in case of near crash. This happens only if the driver decided to brake first
  - Speed regulation system
  - Lane keeping
  - Cruise control system

- **Decide and execute**: the systems process the road environment and the contextual data very precisely and then determines the best action to execute, it does it by itself once the driver has engaged it. Examples include:
  - Autonomous emergency braking system
  - Remote garage parking
  - Highway chauffeur

C. The 6 major systems group

The 4 types of ADAS applications are served by no less than 27 assistance systems, all with standard names that are rarely used publicly by the car manufacturers.

Fig 1.2: ADAS functions impact on safety and automation

Source: PTOLEMUS

We organised the ADAS technologies in the graph above to show the various groups based on activity but also the technical evolution towards increasing automation. Inside each categories, we ranked the functions by their effect on safety with the systems having the biggest impact at the top of each group.

Below is an updated and thorough list of the functions. These functions are reviewed in details in Section II from a benefit and market offering perspective and in Section IV from a technical perspective

Lateral collision avoidance (lane control)

- **LDWS = Lane Departure Warning Signal** - Warns a driver when the vehicle begins to move out of its lane,
- **LKS = Lane Keeping Support** - If the system detects a vehicle moving outside of its lane, it can apply the brakes and partially steer the vehicle in order to keep it in the lane,
- **LCA = Lane Change Assist -** Combines a blind spot detection warning and an active lane keeping support,
- **CTS = Cross Traffic System** - (strictly, an angle collision system) Can detect collisions that happen at intersections and in other angles. The system uses a combination of long, medium, and short range radar in order to detect objects and predict collisions.

Frontal collision avoidance

- **FCW = Forward Collision Warning** - Detects vehicles directly in front and can send a warning signal when it senses a closing speed that could indicate a potential crash,
- **AEB = Autonomous Emergency Braking** - Detects when there is an imminent collision and can assist driver in applying maximum and optimal breaking power. In emergency situations, AEB can also apply maximum braking if driver fails to respond,
- **PPP = Predictive Pedestrian Protection** - Combines all the functionalities of FCW and AEB, but is specifically designed to detect smaller objects such as pedestrians and cyclists.

Cruise systems

- **ACC = Adaptive Cruise Control** - The system can adjust speed and maintain safe driving distance without driver applying brakes or acceleration,
- **A-ACC = Advanced Adaptive Cruise Control** - The first truly Level 2 technology, C-ACC can adjust speed and maintain safe driving distance while also reading the lane markings to keep a vehicle in the lane,

- **Highway Pilot** - The definition of Pilot or Chauffeur implies the system is Level 3+ automation. The highway chauffeur is where a driver can begin taking his or her attention off the road. The driver must retake control when exiting the highway,
- **City Pilot** - Level 3+ system assistance designed to work at low speed, high complexity environments such as reading traffic signals or detecting pedestrians.

Parking systems

- **RVS = Rear View System** - Combines a rear-view camera and parking sensors to send visual and audio alerts when a vehicle nears a collision during parking situations,
- **RCTA = Rear Cross Traffic Alerts** - Detects angled collisions during reversing and can send a warning signal and also apply brakes if the driver does not react,
- **PA = Parking Assistance** - Assists a driver in parallel and perpendicular parking by managing steering, while the driver controls braking and acceleration.

Vision systems

- **NVS = Night Vision System** - Assists driver with night driving by using an infrared cameras to display thermal imaging on a vehicles dashboard,
- **RSR = Road Sign Recognition** - Detects traffic signs on roadways to be displayed on the vehicle's dashboard,
- **AHB = Adaptive High Beam** - Headlights that can automatically adjust the high beam in night driving when no cars are in range of being disturbed. AHB can sometimes also adjust in order to illuminate a curve on the road.

Vital signs monitoring

- **CDD = Cognitive Distractions Detection** - System analyses steering wheel movement, heart rate and facial expressions to determine if the driver is distracted,
- **DMS = Driver Monitoring System** - Uses infrared sensors and cameras to monitor driver attentiveness.

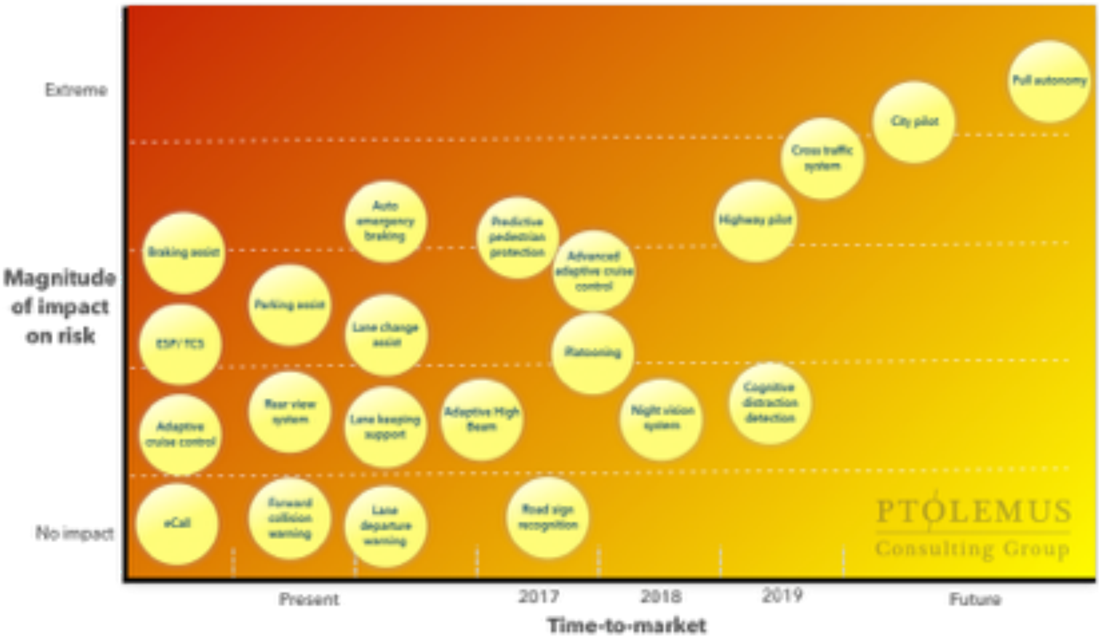
The real issue with this long list is that while the terminologies are complex and not used homogeneously, it is also impossible for service providers, such as insurance or even safety testing companies, to **know immediately what sort of ADAS a vehicle is equipped with**.

The features are also focused on the aspect of safety that matters to the OEMs. They might protect the driver at all cost but very limited attention is given to the frequency of accident types and how those could be mitigated by ADAS.

The arrival on the market of these features is also not related to their pressing need but the technology and costs required. We estimated the time of market entry for each of the core safety functions in the graph below.

This exercise demonstrates that the majority of ADAS features are now available and on the market. The car market has been focused on safety for the last 10 years and critical improvements have been made. Only a few features have yet to be launched or made available in most vehicle class. These feature are however **the ones with the biggest impact on collision risks**.

Fig 1.3: Mainstream safety features most impactful on collision risks



Source: PTOLEMUS

From a driver perspective, while the technology-minded will appreciate to know exactly what their car can do, few will look into the definitions; hence only a few groups have looked at classifying the autonomous ability of a vehicle by levels.

This has proven to be a difficult exercise.

D. The many levels of automation

There are many types of automation and the technologies involved as well as the requirements on the driver and the multitude of factors affecting the vehicle's capabilities make it impossible to compare equipped vehicles side by side fairly. This is why we believe **they are a necessary evil** for all the stakeholders involved to understand autonomous features in the same way.

The 2 main classification models and their shortcomings

There are different standards which clarify levels of vehicle automation. For the sake of clarity, we will focus on the 2 most relevant ones, those **defined by the Society of**

Automotive Engineers (SAE) and the levels used by the United Nations Economic Commission for Europe (UNECE). The US National Highway Traffic Safety Administration (NHTSA) also used to have its own classification, but they now refer to the SAE.

The SAE levels illustrated below are used everywhere - especially by NHTSA in the US to define safety requirements, but **they are widely misunderstood**.

Fig 1.4: Society of Automotive Engineers (SAE) levels of automation

SAE Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capabilities (driving modes)
Human driver monitors the driving environment						
0	No automation	The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver assistance	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 performs all remaining aspects of the dynamic driving task	Human driver + system	Human driver	Human driver	Some driving modes
2	Partial automation	The driving mode-specific execution by one or more driver assistance systems of **both steering and acceleration/ deceleration** using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task	**System**	Human driver	Human driver	Some driving modes
Automated driving system (system) monitors the driving environment						
3	Conditional automation	The driving mode-specific **performance** by an automated driving systems of all aspects of the dynamic driving task **with the expectation that the human driver will respond** appropriately to a request to intervene	System	**System**	Human driver	Some driving modes
4	High automation	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	System	System	**System**	Some driving modes
5	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	System	System	System	**All driving modes**

Source: SAE International, Blue denotes human control and green denotes machine controlled

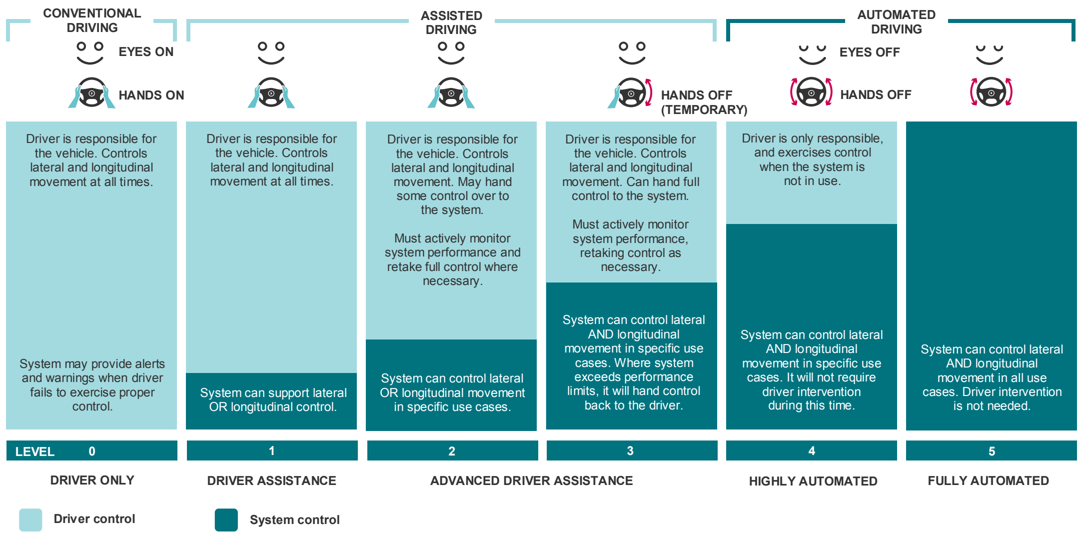
SAE levels are defined based on the activity and responsibilities of the driver/ user while at the wheel, not based on the capability of the vehicle autonomous system. Also, the levels cannot define all the repercussions that the technology will have on delivery model, usage and liability.

A good example of the confusion is the recent announcement by Ford's CEO that **the company will offer a fully autonomous driverless vehicle at SAE Level 4 by 2021**. From the definition below, Level 4 is restricted to some driving modes, defined by areas of usage (Operating Design Domains as NHTSA defines it) and that if the driverless vehicle is operating only in a strictly define geographical area with conditions attached to the use, then it is a **Highly Autonomous Vehicle (HAV)**, not a fully autonomous one.

Another confusion comes from Tesla. The company's "Autopilot" function blurs the lines between levels 2 and 3. While the car is expected to provide level 2 assistance, its features are so advanced they **entice the driver into believing the car is autonomous**.

The 2 reasons why the Tesla is not a level 3 vehicle are, firstly, that it is still illegal to drive with your hands off the wheel and, secondly, Tesla cars (and others similarly advanced) cannot yet judge if there is enough space available in the adjacent lane in which to overtake then come back to the initial lane.

Fig 1.5: The UK representation of the SAE levels



The levels of assistance and automation are adapted from the Society of America Engineers J3016 Standard "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems" (http://standards.sae.org/j3016_201401/). While these are not formally recognised by the UK Government or the United Nations World Forum for Harmonisation of Vehicle Standards, they are seen as a helpful guide to the technology.

Source: SAE International, UK Department for Transport

The SAE levels have therefore been re-used and more information has been added to them to include other areas. The UK's recent consultation on how to address the impact of automation in the insurance sector included a **different definition of the 5 levels** based on the SAE template.

The consultation added the concept of liability into the equation and defined more precisely how far the driver has to be in control. The concept of **shared liability** depending on whether the system is on or off is referred to in the graph and the UK's consultation.

The representation of the levels is also an attempt at making the levels user friendly with the short cuts hands and eyes on and off.

Yet by and large, **these levels are not ready for prime time** in terms of consumer communication, as **they remain unclear to most people in the industry, let alone drivers**. The OEM representatives we interviewed were vague on the use of these levels in their marketing. Today, they much prefer to use the term of "assistance features".

In public announcements however, the confusion is lead by manufacturers and the press.

"Full automation" is generally used wrongly and should never be taken at face value in the current messages from manufacturer's CEO.

The level of automation will depend on the environment

One of the most influential updates in NHTSA's Federal Automated Vehicle Policy guideline is the definition of the **Operating Design Domain (ODD)**.

Fig 1.6: Illustrative examples of Operating Design Domains (ODD) and their restrictions

Source: PTOLEMUS

The functionalities and "abilities" of a specific vehicle will be determined by their SAE Level. For each ADAS system at each level, NHTSA defines the ODD as the circumstances in which the system is capable of operating or, put another way, when it will require the driver to take back control (i.e. freeway driving, self-parking, geofenced, urban driving, adverse weather, poor visibility).

So a SAE Level 2, 3 or 4 vehicle could have multiple systems, one for each ODD. A SAE Level 5 vehicle will have a single automated vehicle system that performs under all conditions.

This is critical because the OEMs are responsible for defining the ODD of the vehicle and to send that definition to NHTSA in their Safety Assessment Letter. In turn, we should be able to expect that based on these letters, each vehicles ADAS capabilities and ODD will be accessible to the drivers **and to their insurers.** The graph below illustrates how ODDs could be defined for each Levels and what other parameters will need to be considered by the drivers when understanding the capabilities and shortcomings of the assistance functions.

The SAE level definition will not be used for type approval

Since the US motor industry is self-regulating, while the NHTSA recommendations on safety requirements follow the SAE levels definition, only these will apply there. The rest of the world is submitted to pre-market approval. In the case of autonomous functions, the safety requirements are defined by **UN Regulation 79**. This regulation is the fundamental instrument by which all type approval is set in Europe, Japan and in many other countries, therefore it should certainly not be underestimated.

50 countries follow the World Forum decisions and use them to define the rules on vehicle homologation. These counties are bound by these requirements. Many more simply refer to the requirements, meaning they take them as such and paste them into their own national regulations. Only the US, China and India are not directly engaged in the World Forum, but their car companies are. At country level, a framework for co-operation exists and is used to agree on meta-regulations that are then transposed into law individually.

Their approach is a lot more narrow. The working group restrict its scope to:

- **ACSF**: **Automatically Commanded Steering Function;** a function assisting the driver in following a particular path, doing a low speed manoeuvre or parking. The function has a **speed limit of 10 km/h**. The category includes park assist or remote controlled parking,
- **CSF**: **Corrective Steering Function;** a function that assists the driver in maintaining the basic desired path of the vehicle, or that influences the vehicle's dynamic behaviour. A typical example would be lane keeping assist.

In the guidance to the **GRRF** (the Working Party on Braking and Running Gear), the proposition to amend the Regulation 79 (R79) that controls the 2 functions above **stops short at SAE level 3 automation**.

Also it makes very clear that all the categories including partial automation are restricted to "Highways" defined as, "a road section which is not dedicated to pedestrians or bicyclists and which has a [physical or constructional] separation of traffic moving in opposite directions." It is expected that the safety requirements for ACSF's speed limit to be taken out will be finalised in September 2017.

We detailed **below** the categories used by the Regulation 79 and suggested an equivalent SAE Level.

It is striking to see the difference in ambition between the 2 categorisations. However, the UNECE categories are defining the evolution of ADAS from today's driver assistance on highways to the first level of automation.

Fig: 1.7: Correspondence of UNECE autonomous function categories with SAE levels of automation

Source: UNECE, SAE, PTOLEMUS

For the purpose of homologation, it is important that the functionalities of a system be extremely precise. Depending on how they are defined and explained, the vehicle could considered level 2 or 3.

For example, the **Tesla S was given type approval in the Netherlands**, and from there *de facto* approval in the rest of Europe. However, the definition of the *Autopilot* function made through the homologation was not the same as the system later made available following Tesla's over-the-air software updates. Initially, Autopilot was defined as a "corrective system", rather than the more advanced lane keeping, cruise control system defined today. The regulation has now brought clarification to the difference.

Still, the line is vague, so the UNECE **categories have become narrower and more precise.** At level 2 the driver has the **obligation to monitor the situation outside and inside the car**. At level 3, the driver only has the **obligation to monitor the proper working of the system and not the environment.** This will depend on what risk the manufacturers choose to take.

Only Category E is a system able to drive fully autonomously as well as doing autonomous lane change without a confirmation from the driver. It is however **confined to highway conditions**.

A member of the UNECE regulation 79 working group mentioned: "We do work on integrating the SAE levels in our regulatory framework, but when we talk about the requirements, we move away from them. We want to ensure the system that is ultimately able to drive on the highway autonomously complies with what people's expectation of Level 3 will be."

How the SAE levels can be used by the industry

We believe that as more autonomous vehicles come on the market, the only words used in public communication will be **"automated"**, "**autonomous**" and "**driverless**". Some will make the distinction between automated functions (meaning levels 1 - 3), while autonomous and driverless will relate to the higher levels where human intervention is no longer required. People will not hear or remember levels of automation and what they relate to. How it works will not matter and what it does will have to be **explained at various stages** of the buying/using process and then repeated in the vehicle throughout its lifetime.

Naming the functionality is also a dangerous activity. The repercussions of Tesla's so-called "**Autopilot**" have been extremely negative in certain respects. Manufacturers are now avoiding the use of words such as "autonomous" or "pilot" until they are confident they can offer the service as the general consumer will perceive them. **We will look at 15 of the leading OEMs' strategy and responsibility in great details in Section III.**

Today, OEMs simplify the segmentation in 2 categories:

- **Safety-based features:** Toyota calls that track of research *Guardian*, Nvidia calls it *Co-Pilot,*
- **Automation**: Toyota calls it *Chauffeur*, Nvidia calls it *Auto-Pilot*.

As an industry, however, it is essential we all understand the levels of automation in the same way as well as recognising **what needs to happen to go from one to the next**.

L1

The first level we consider here is level 1, where a vehicle is **assisted by only one ADAS feature** such as lane keeping alert. **Most new vehicles have such features today**, the importance of level 1 is in its adoption by OEMs as a default feature as opposed to a paid-for option. The adoption and volumes of all other automation level will be affected by level 1.

L2

Level 2 is strictly defined by assistance and safety. ADAS functions as described above are the core of what makes level 2 but it is not automation as such. The most common is **Autonomous Emergency Braking** (AEB) which at its basic level will avoid or lessen a frontal impact. US OEMs, under the request from NHTSA have announced this specific technology will be voluntarily included in all new vehicles after 2018. In Europe, the technology is already mandated in trucks since 2016 but we cannot see a mandate on the horizon for consumer vehicles. It is expected the **European manufacturers will be forced to follow the US ones to compete in each market.**

Once the reserve of the luxury segment, ADAS is now seen in an increasing number of models, right down to the mid-size and compact segments. However, cruise control and lane keeping technology are also part of the ADAS long list of assistance techniques and once two are combined they can produce a limited version of an assisted driving system.

L3

Level 3 is defined by SAE as the **first step to automation**, however, in practical terms, we believe it will be restricted to mostly a **technical update of what we see in level 2 today**. Specifically, monitoring of the driving environment will improve but **fallback will still be left to the driver**.

From a product perspective, level 3 automation will be defined by **advanced cruise control capabilities, type approval and changes to the highway code** that will allow drivers to take their hands off the wheel under certain circumstances. The new homologation is also expected to require accident data logging and the definition of the ADAS functions to be included in (or attached to) the VIN number.

From a liability perspective, it will not be any different that level 2: the driver will still be fully responsible for what happens to the vehicle at all time. True automation will be only seen at level 4, that next level in automation will have far bigger consequences.

Due to the proliferation of OEM involvement in mobility service platforms such as car sharing and ride hailing and the potential for vehicles designed exclusively for use on these platforms, we have decided to split level 4 into two categories: non-driverless and driverless vehicles. **We examine the growth of mobility services and OEM involvement, as well as their relationship with higher autonomous vehicles in section VI.**

L4

The SAE definition of level 4 is a much bigger technical challenge requiring **complete redundancy** and, potentially, 3D maps as well as V2X communication capabilities to help deliver this redundancy. This will enable the vehicle to have complete control over all aspects of the driving task. On top of that, high automation impacts the definition of driver and manufacturer and, therefore, **liability in the case of a crash or incident.** We will analyse how the liability aspect will change in section IV.

L4D

This is why **we decided to split this level** and clarify the difference between automated and driverless cars. The need to re-engage the driver when the system is not capable of driving in autonomous mode is clear in level 2 and 3. At level 4, it is very much up for debate whether there will be a **choice to drive the vehicle manually or not**. Which is why we have seen two types of vehicles and OEM strategies evolving.

One is a step by step evolution from level 3 to 4 with a linear progression of the automation capabilities. The other is a jump to driverless level 4 whereby the vehicle autonomous platform is only managing its own driving capabilities and **not having to account for or manage human driving** as well as responsibilities towards the vehicle maintenance for example.

In turn, this suggests that if level 4 autonomous vehicles were to be **driverless, they would not be owned** by the passenger. This is likely to be the case because of the inability to use the car outside of the defined geographical area (such as a specific city centre) and the high initial vehicle cost. Ford, for example, has clearly stated that its first level 4 driverless cars will be designed for use on ride hailing and mobility platforms. This is clearly supported by a compelling business case, which we explore further in section VI.

We could foresee the driverless car to be at first a **shuttle** driving passengers on one or very few routes such as the trials taking place in Paris, Lyon or Milton Keynes. Then we can expect it to evolve into a **tram** with the user choosing its route among a closed choice - such as in the trial taking place in Singapore. The last stage before becoming a black cab with the Knowledge of an entire city, is for the driverless car to be a **bus** with the user able to choose anywhere it wants to go inside the city but following only a set of prescribed routes.

A level 4 vehicle with the option of driving would certainly be a luxury vehicle the driver could switch on autonomous mode and either work or fall asleep in. The consumer vehicle is likely to be a luxury brand because of the high initial cost of the technology. This would make long trips possible with the driver **choosing particular parts to drive on and letting the car drive the rest**. We expect this type of vehicle will appear on the market after level 4 driverless vehicles because they will be driving longer distances on a much wider variety of roads.

For this reason level 4 vehicles will require more testing in a more diverse set of conditions. Level 4 driverless will be confined to specific city centres/urban locations.

L5 The **level 5 autonomous** vehicle will be able to drive anywhere in the country under any circumstances. We will describe in Section IV the different technical requirements for each of the levels.

In the graph below, we have presented some of the key requirements and responsibilities for each level of automation from the perspective or various stakeholders. Note, that the predicted dates below are a best scenario forecast based on the most favourable geographical markets such as the US, Germany or the UK.

We sum up in the next chart the different levels that we will use in this report.

Fig 1.8: The levels of automation and their impact

	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 4 DRIVERLESS	LEVEL 5
Example	*Ford Focus 2016*	*Tesla Model 3*	*Mercedes E Class*	*Navya Arma shuttle*	*Rolls-Royce Vision Next 100*
Launch date	**2010**	**2017**	**2021**	**2021**	**2030?**
Enabling technologies	Sensors (Camera, radar)	3D / HD maps	Lidar, V2V, V2I	Lidar, V2V, V2I	Full AI HA GNSS
Defining application	ADAS	Advanced Cruise Control	Autonomous car	Driverless car	Driverless car
Regulation change required	Type approval	Highway code	UNECE R79	City mandate	International transport laws
Driver responsibility	Full liability	Full liability	Partial liability	No liability	No liability

Source: PTOLEMUS

Autonomous vehicle platforms

We will later refer to the "**upfitting approach**" by which a tier-1 provider is sharing a similar solution to OEMs for them to build an autonomous car without having to spend the R&D necessary in creating the solution by themselves.

The platform can be used on existing vehicle models, creating an opportunity to upgrade current vehicle brands. While this is expected to be beneficial for small OEMs, the reality is that the AV market is so young, so large OEMs have also invested in this strategy.

As an example, the Mobileye autonomous platform is being considered and tested by BMW, GM, Nissan, VW and Volvo. Other providers such as comma.ai have also brought upfitting solutions to the market, as we shall explore in much greater detail in Section V.

Providing a similar autonomous vehicle platform across vehicle brands will help gain time to market (Mobileye expects its level 2 enhanced ACC function to be on the road in 2018 with Nissan *ProPilot*), it will also help the regulators identifying and validating ADAS features.

E. Today's OEMs' involvement

Luxury brands are by far the most active in the development and commercialisation of ADAS solutions today. Some integrate the full offer into their vehicles, while others offer optional packages.

For these manufacturers, it is a way to demonstrate advancement and technical superiority. It is also a way to **provide their drivers with unique features** that only a very high end vehicle can offer. Some of the various automated technologies on offer will make it through to mass market adoption, or, in the case of AEBS, become mandatory. Either way, the investment and effort will be well worth it.

Mercedes F 015

The Mercedes F 015 is a perfect example of the level of investment being made by premium brand OEMs. Aside from the various autonomous functions of the vehicle, Daimler is promoting the model as a solution to future mobility needs. Described as a forerunner of the "mobility revolution", the F 015 focuses on space, innovation and luxury, expressing the value of an autonomous vehicle to society at large.

"Anyone who focuses solely on the technology has not yet grasped how autonomous driving will change our society. The car is growing beyond its role as a mere means of transport and will ultimately become a mobile living space," argues head of Mercedes-Benz cars, Dr Dieter Zetsche.

In this sense, the F 015 has been designed to reflect this kind of future, both in terms of its autonomous functions and aesthetics. It is also a good representation of the difference between OEMs' ambitions; Daimler was already showing this level 4 automation concept in January 2015 nearly 2 years earlier than BMW's Vision Next 100 announcement.

Most OEMs are developing autonomous solutions but they are at various stages of advancement:

- **BMW** has established very public strategic goals related to automation with different vehicles aiming at 3 segments and levels of automation. Like Ford, it has publicly committed to producing a level 4 vehicle by 2021 and remains one of the most active OEMs in terms of striking relevant partnerships,
- **Daimler** already has a broad ADAS offering which is rapidly expending across its range. The company has made huge investments in R&D as well as numerous acquisitions in the mobility space, which have propelled it in front of many of its competitors,
- **Fiat Chrysler Automobiles (FCA) and Honda** have both come later to the game than some of the luxury marques and, representing an entirely different strategic approach,

have partnered with Google's Waymo, with the aim of installing Waymo's complete autonomous solution in their vehicles,

- **Ford**'s CEO, Mark Fields, has been very vocal about the company's goal to launch a level 4 driverless vehicle by 2021. The company has also extensively invested and partnered in the area, yet so far ADAS has not been widely introduced into their range. Their $1 billion investment in software start-up ARGO AI in February 2017 is a clear show of intent,
- **GM:** Cadillac is planning to equip its vehicles with vehicle-to-vehicle (V2V) communication technology. Their vehicles already include several ADAS solutions and they are expecting to launch more advanced cruise systems in the next two years. Like Ford, the $1 billion acquisition of autonomous software development start-up Cruise Automation reflects the group's clear ambition to fully develop its own autonomous platform,
- **Jaguar Land Rover** partnered with Altran to develop an open software platform. Bringing together cutting-edge industrial and engineering techniques the company lead a testing program on autonomous technologies in partnership with UK universities and the Transport Research Laboratory called *Towards automation,*
- **Renault Nissan:** The alliance has struck some very ambitious partnerships and has been move active than some other European OEMs in terms of introducing automation to its fleet. Nonetheless, much of the activity has focussed on Nissan's Infiniti brand to the neglect of other marques,
- **Tesla** has been the first manufacturer to call its adaptive cruise control system an "autopilot". Misuse of the function has lead to several high profile incidents but the company is pursuing its "Beta" strategy with its new autonomous platform launched in October 2016. We will assess the consequences and lessons learned from the Tesla approach in Section II,
- **Toyota/Lexus:** Both brands offer several ADAS solutions generally sold as standard. While the OEM has not made great announcements on automation, it was an early partner of the Google car project and has since launched some ambitious stand-alone initiatives,
- **Volvo:** Has created an alliance with Uber, who are installing their own autonomous systems in Volvo models for testing and is deploying Volvo Drive, one of the largest autonomous driving testing programmes with vehicles in Sweden and in the UK,

A complete assessment of 16 OEM's strategy and offering can be found in Section III. **16 detailed OEM profiles are included in the full study.**

Waymo and the "Google Car"

Google continues to follow a very different approach towards higher level (4) automation by pursuing full automation technology, ignoring any efforts to commercialise semi or highly autonomous solutions below level 4. Google believe that in order to effectively reduce car accidents, it is fundamental to completely remove human error. The company argues that only through full and complete automation can this be achieved.

In recent years, Google has hired a number of technical and industry experts from the automotive world, including the appointment of former Hyundai president and chief executive John Krafcik, who now heads up the company's re-branded autonomous vehicle division, Waymo. Former Tesla autopilot software engineer Robert Rose, has also been brought into the company to help with development of the level 4 software.

It has been reported that Google are rethinking the design of the car and have already patented two of their autonomous vehicle designs. These relate to communication with pedestrians and a car without a steering wheel and pedals. However, recent conversations with Waymo's CEO clearly indicate that the company is more **focused on building a complete autonomous solution, including AI and all hardware components,** rather than the car itself; essentially the Android model for cars. The partnerships with Honda and FCA support this.

Fig 1.9: OEM involvement in ADAS in 2017

Source: PTOLEMUS

2. What is at stake here?

Automation, from assistance to robotisation will change everything, beginning with transport, but also affecting manufacturing, planning, employment laws, taxation and many other sectors. That said, it won't change everything everywhere.

Global car brands usually make 3 versions of their global model: the EU version (sometimes also sold in China, India and Japan, the US version for North America and a third version for rest of the world (RoW) ie: countries with few or no regulations. For this last group, the OEM will often downgrade the equipment related to safety of their vehicle in order to reduce costs. Hence, in these countries ADAS will generally be sold at a later stage than in the EU and North America or will be provided as an option.

For this reason, we believe that autonomous vehicles (AVs) will impact the Western, Indian, Chinese and emerging Asian markets at the completely different speeds. The cost of the vehicles in those markets is far lower and also because the volume of vehicles is expected to grow much faster than in Europe and North America, becoming the largest markets for motor insurance by 2025 in terms of volume.

China is today the first market for premium brands. It could become the biggest market for the latest safety technologies. Considering that the cost of ADAS features will decrease with volumes, Chinese car makers could be providing standard ADAS equipment very quickly

In this section, we will focus on the impact of automation where it will be felt first, i.e. North America, Western Europe and North-East Asia.

A. Analysis of the impacts of automation

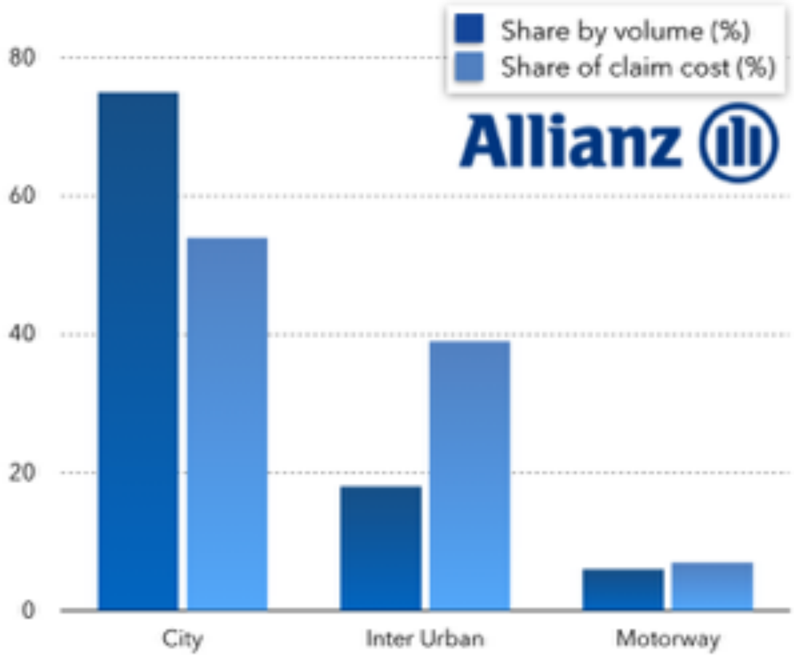
Safety: the core benefit

Autonomous functions provide two principal functions. On the one hand they provide additional comfort to the driver and on the other they reduce the risk of an accident occurring. While all improve safety, **some ADAS functions are more clearly orientated towards comfort**; services such as cruise, parking and vision systems clearly are good examples. Vital signs monitoring, frontal collision avoidance and lateral collision avoidance however do little to enhance the driver's comfort.

ADAS systems are expected to react **10 times faster than human** drivers, yet the complexity of the decisions is evolving all the time and the number of calculations the processor will need to take will also increase

It is said that 90% of crashes are linked to human behaviour, yet we do not know how many incidents will be linked to autonomous functions in the long term. On the whole, human drivers are fairly safe, ADAS should make them safer, not add a level of risk.

Fig 1.10: Bodily injury claims by accident location



Source: Allianz Centre for Technology (AZT)

Within each ADAS group, however, there are individual discrepancies such as parking systems that only alert the user regarding a potential impact and those which offer fully automated parking. Their impact on safety will, resultantly, differ widely. Studies conducted by the Allianz Centre for Technology (AZT) have shown that **safety is not improved by parking systems that combine rear camera and proximity sensors**.

While a quarter of the accidents are linked to parking, it is while getting out of the parking place, not while parking that the collisions occur. We will assess and quantify the impact of various ADAS function on safety, claims and premiums in Section III.

To look further at the safety impact of ADAS, we need to identify where the incidents are taking place. The graph above shows how the majority of the claims are from collisions in an urban environment. **In fact 75% of the collisions occur at speeds of less than 25 mph**.

This is striking because the majority of ADAS functions are aimed at safety on the highways. This apparent contradiction is linked to the fact that **OEMs prioritise avoiding severe accidents and the loss of lives**, insurance companies want to reduce the number of claims.

Legislation will impact the speed at which some ADAS features are integrated

As an example, **brake-assist functions** (which ensure that the brakes are applied fully in cases of an emergency stop) have been mandated for all new cars and light commercial year involving pedestrians avoided.

Braking assistance systems not only reduce the risk of injury for pedestrians, they also help prevent rear-end collisions. A surprising number of drivers do not use the brakes immediately before a collision and those that do are not necessarily applying the vehicle's full braking capacity. This is primarily because they are afraid of locking wheels and losing control of their car.

Since November 2015, heavy goods vehicles (HGVs) in Europe also have to be equipped with **advanced emergency braking systems (AEBS)** and **lane departure warning systems**.

Automatic emergency braking uses radar, lasers and cameras to see as far as 650 feet in front of a truck; about three times the typical follow distance on highways. They first **signal a driver of upcoming obstacles** though a combination of optical, acoustic or haptic signals and, if the driver does not react, will **slow or stop the vehicle**.

EU Regulation No. 347/2012 specifies the technical requirements and test procedures for these advanced emergency braking systems (**AEBS**). One with the vehicle approaching a moving target, the other with the vehicle approaching a stationary target. The regulation specifies two "levels" of limit values on the **timing of the warnings** and on the **vehicle speed reduction** to be achieved in each of these tests, with the level 2 requirements being more stringent.

To allow time for the development of suitable systems for lighter vehicles, trucks with hydraulic braking systems and vehicles with mechanical rear suspension systems, the level 1 limits are only applied to buses and trucks between 8 and 12 tonnes as well as trucks equipped with pneumatic or air/hydraulic braking systems and with pneumatic rear axle suspension systems.

Level 1 AEBS became mandatory in November 2013 for new types of vehicle and mandatory for all new vehicles in November 2015.

Level 2 AEBS became mandatory from 1 November 2016 for new types of vehicle and will become so from 1 November 2018 for all new vehicles.

Since the **lifecycle of large trucks has been markedly reduced in recent years** thanks in part to steadily rising fuel economy standards, new safety technologies such as AEBS will penetrate the commercial fleet faster than in the consumer vehicle market.

In the US, the past 10 years have also seen an explosion of automated systems on trucks, including **adaptive cruise control**, **lane-departure warnings** and **electronic stability control (ESC)**. ESC became mandatory for light vehicles in North America in 2011 and in Europe in 2014. According to tier-1 supplier Bosch, 59% of light vehicles sold worldwide in 2014 were equipped with ESC.

The US National Highway Traffic Safety Administration (NHTSA) was also considering mandating AEBS since large commercial trucks have been the cause of an increasing number of accidents in the last five years. Instead, a voluntary agreement from US OEMs was announced whereby **they all agreed to include AEB by default from 2018** onwards.

While miles traveled and the number of registered trucks has held relatively steady, the rate of accidents has increased from 29.3 fatal crashes per 100,000 trucks in 2009 to 36.9 per 100,000 in 2013. In 2013, **64% of those crashes involved frontal impacts by trucks** - crashes that could have been prevented or mitigated by automatic braking.

The testing agencies have already included AEB in their test, but the technology will continue to evolve and with it the test and expectations of what it can do. For example, UK testing agency **Thatcham called for LCV operators to consider AEB** in vans as it has been suggested to avoid 38% of the read-end collisions.

Thatcham's findings were validated by another study published in September 2016 by **If P&C Insurance** (owner of the Volvia insurance brand) **and Volvo**. It concluded that rear-end frontal collisions were reduced by 27% for cars with low-speed AEB compared to cars without the system. This goes up to 37% for low severity incidents.

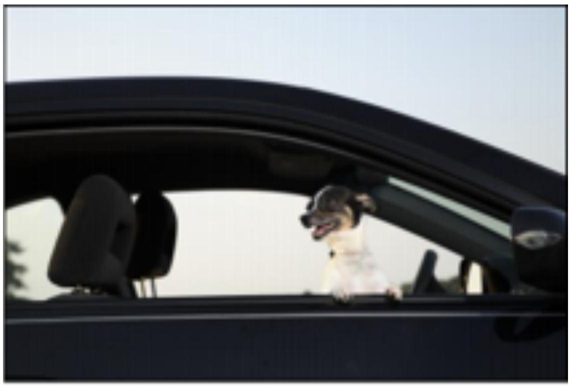
This suggests that the safety system fails to avoid the collision most of the time. The reasoning behind this is explained by a number of factors:

- AEB mitigated but did not completely avoided the crash because the speed of the vehicle was too high,
- If the relative speed is less than 15kph then avoidance with all systems was 100%,
- Collisions were not avoided because they were not registered by the sensor that looks for a frontal collision risk and cannot include side or "less straight forward" collisions.

Optional AEB can cost from €230 to €1650 (depending on the package) and the next steps are **pedestrian AEB** and **Cyclist AEB.** We will investigate in detail the evolution of safety testing and its impact of the adoption of ADAS features in Section III.

The potential to reduce claims

The ability of each autonomous solution to reduce accident losses will depend on the level of sophistication. In theory, **the more sophisticated the solution, the greater the reduction in both the severity and frequency of accidents**. If the solution is able to exert control over the car, rather than simply warning the driver, we expect there to be a more significant outcome.



It is important to consider that accident reductions as a result of **ADAS can overlap with other safety features**. Volvo, for example, includes a pedestrian airbag on some models which opens immediately on collision across the frontal part of the vehicle. This could reduce the consequences of an accident, leading to a reduction in claims.

The aim of an automatic braking system is of course to avoid any collision altogether, however even if the impact is simply lessened, this will reduce the amount of the overall claim. The effect of some of these solutions coming on the market is already reflected in the price of insurance, with some insurers such as **Allianz in France offering up to 25% discounts for models with certain ADAS features installed**.

While both sets of services have a role in increasing the public acceptance and appeal of autonomous vehicles, only the outright safety orientated features will have an impact on insurers' risk assessments.

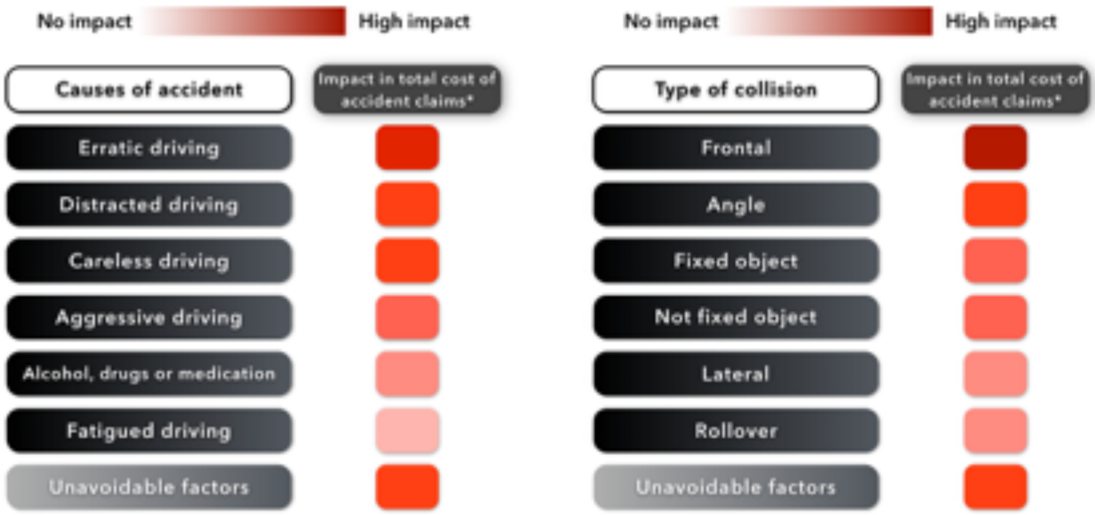
On average, **accidents typically represent 55% of the total cost of the insurance policy**. The premiums will include these costs, plus profits and taxes. In order to analyse the impact of automation on insurers we have arranged the main costs to the motor insurer into three main categories:

- **Accident claims (55%):** These represent all payments made to the policyholders relevant to the cost of the accident, whether third party liability or own damage,
- **Non-accident claims (15%):** Referring to the claims that cannot be reduced by improving safety, including issues such as theft and fire, fraudulent claims and other damages such as vandalism or broken glass etc.,
- **Operating expenses (30%):** Representing all other costs related to the management and commercial activity of the policy.

The main causes of motor accidents can be classified either according to cause or type of event.

We estimate that up to 81% of accidents can be classified according to the list below and could be avoided through the introduction of ADAS functions.

Fig 1.11: Main causes and types of motor accidents



Source: PTOLEMUS *estimated impact based on historical data, frequency and severity of motor accidents

As illustrated in the table, **erratic** driving represents the leading cause of accidents, followed closely by **distracted** and **careless** driving. Frontal and angle collisions have the greatest impact on accident claims costs and could also be mitigated.

The frequency and average cost per accident determines the overall impact on the total cost of claims. Each category can also be subdivided into more specific causes and types of behaviour such as mobile usage, visual and verbal distractions.

The impact on the total cost of claims is estimated according to the consequences, severity and frequency of the accident. The higher the severity, the higher the cost. Severe accidents however, are less frequent.

Causes of accidents

If we analyse the individual causes of accidents we can observe the following:

- **Erratic driving** has the greatest impact on claims losses. This behaviour can include avoidable errors made by the driver either because of poor reactions to a given situation or lack of adequate training,
- **Distracted driving** also represents a significant and growing factor, with the growth mainly attributed to the use of mobile phones,
- **Careless driving** is often linked to erratic and distracted driving, but also refers to drivers choosing not to follow indications,
- **Aggressive driving** causes accidents less frequently, although the consequences tend to be more severe,
- Accidents resulting from **drivers under the influence of either drugs, alcohol or medication** as well as those attributable to fatigue and medical seizures are less frequent, but similarly tend to have worse consequences.

If we analyse accidents by type of collision we can observe that these mainly occur vehicle to vehicle and that frontal collisions represent the greatest impact, followed by angle and lateral.

Collisions with non-fixed objects tend to result in the most severe outcomes and these can include pedestrians, cyclists and animals, excluding other motor vehicles.

We estimate that **19% of accidents occur as a result of circumstances that cannot be controlled by the driver**, such as mechanical failure or adverse weather conditions (*unavoidable factors* in the graph above). At this point, we are able to link ADAS solutions to causes of accidents and identify which could be solved, noting that some categories may overlap. The graph below is a simplification of the measured impact of ADAS on claims, in Section III, we quantify that impact.

Braking systems have a significant impact on the reduction in claims, mainly because they are activated 100% of the time and tackle the most common causes of accidents such as rear end and angular collisions.

Cruise systems could also be one of the most effective ways to reduce claims as they are **able to integrate a number of ADAS solutions**. However, unlike braking systems, these are not always active, either due to driver choice or an inability to perform under all driving conditions.

Vital signs monitoring systems have improved to include the possibility of taking over from a driver in case of loss of consciousness, although current systems simply provide alerts, rather than full driving automation.

Fig 1.12: Estimated impact of core ADAS functions across 3 markets

Source: PTOLEMUS

A complete analysis of the impact of automation on claims and premium can be found in Section III.

The evolution of cruise systems

We consider automation to represent the evolution of cruise systems, complemented by ADAS solutions. We predict that highly autonomous and fully autonomous vehicles will have frontal collision avoidance systems, while partially autonomous vehicles will have emergency brake assist functions.

Cruise systems are the ADAS solutions which determine the automation level. Partial automation includes advanced adaptive cruise control and traffic jam assist. High automation refers to advance traffic jam assist and highway chauffeur. Full automation includes highway and city chauffeur, which is fully autonomous in a driving environment.

Fig 1.13: The evolving sophistication of ADAS solutions

	Level of sophistication		
	Partial automation	High automation	Full automation
Frontal collision avoidance	Emergency brake assist	Predictive emergency braking system	Predictive emergency braking system
Cruise systems	Advanced adaptive cruise control + Traffic jam assist	Advanced traffic jam assist + Highway chauffeur	Highway chauffeur + City chauffeur

Source: PTOLEMUS

The definitions are important because the quality of the cruise control will create the blur between ADAS and automation. This why a number of OEMs have mentioned they would “avoid Level 3”. In fact, the natural evolution of cruise control in non- autonomous car will be indistinguishable from Level 3 automation from the perspective of the driver.

Of course depending on the type of automation included in the vehicle, the possibility to reduce accidents will vary greatly. Additionally, the length of time during which cruise control is used will affect claims.

We assess the evolution and compare the different cruise systems and their specifications in details in Section IV.

Impact of ADAS on the insurer's Loss Ratio

We define the insurer's loss ratio as illustrated here and analyse the impact of automation on each of the elements:

Acquisition

The new in-car communication system embedded in autonomous vehicles improves customer relationship long beyond warranty, repair and assistance.

Acquisition for OEM insurance is improved, **for insurers it is made more difficult**. UBI and other existing digital insurance products have the power to counteract that. They create stronger links between drivers and insurers and provide for data exchange channels which the insurers can use to cross and upsale.

In the medium term, it is expected that the OEMs take more ownership on this channels. **Acquisition costs will be reduced for captive insurers**. They will become more prevalent at level 3 and above.

Writing

Underwriting risk will be impacted by connected vehicle data first as we have seen in the case of usage-based insurance. New datasets availability and a growing understanding of **how to use car and driving data have transform risk writing**.

As with UBI, the simple fact that the telematics insurance option is chosen is a tell-tale sign the driver will be safer than the average (with the exception of young drivers in the UK who do not have a choice). This is often referred to as **positive selection**.

We expect **a degree of positive selection will also apply to ADAS customers**. In the first instance when they choose the optional active safety features in any range of vehicle. Later on, as Level 3 Automation (L3) vehicles appear, and a lot of the safety features are included in the vehicle as standard, **underwriting will rely extensively on car and route data analysis** the OEMs will have done before launching the new vehicle.

Servicing

Car connectivity opens new opportunities in servicing insurance policies. There are a number of trials today using car data in order to provide competitive and differentiating value-added services such as Stolen Vehicle Tracking (SVT), breakdown alerts and road side services with diagnostic data, fuel efficiency assistance …etc

However, to this day **none of these insurance offers have created volume or revenues**. The investment into the on board units (OBU) as well as the platform and the integration into the various departments of the insurer (marketing, product, underwriting and in some case claims management) has generated huge cost.

With autonomous vehicles, **the cost of servicing insurance could even increase** as more policies have to include UBI devices or apps in order to price the coverage based on the share of the mileage done in manual or autonomous mode.

The alternative would be to use OEM data requiring dedicated agreement, which suggests there is a data platform in place for the information to be transferred "one to many" - or ideally "many to many".

Claims

The impact on claims will be looked at in much more detail and quantified in Section III.

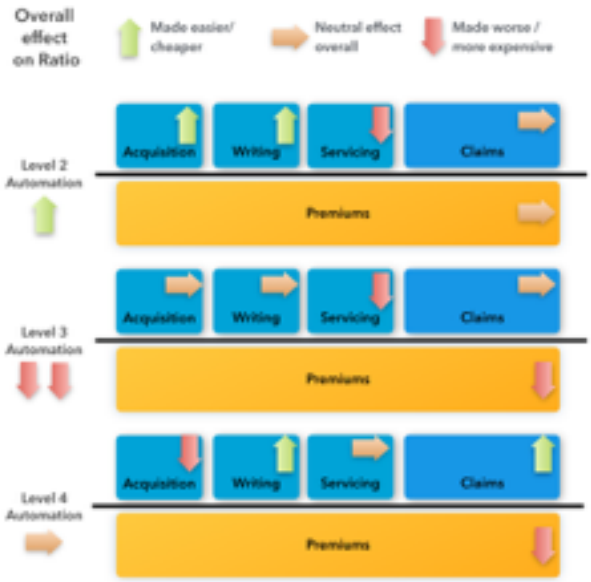
For claims, the level of automation changes the impact. Level 2 AEB has already started to have an impact on claims frequency and severity, however, **the vehicle technology has an opposite effect on repair cost**. We believe that at level 2 the impact on claim is negligible.

At level 3, OEMs could be required to assume at least some degree of product liability, as is already the case for trial/test vehicles in the US. If this becomes the case for all level 3 cars the cost of claims should decrease from the personal insurance perspective. Yet, **non-autonomous vehicles crashing into Level 3 vehicles will result in very high claims average**. Again, negating the benefits in saved accidents.

At level 4 and driverless: Google's fleet has an outstanding safety record so far, with only one, low speed, crash supposedly caused by their level 4 adapted Lexus and none recorded in their level 4 driverless model. Also at level 4, most of the trips autonomous vehicles are expected to make will be low-speed urban commutes. As long as the level 4 vehicle is a shared driverless one, the risk from potential accidents will be low and the claims lower too as they should not endanger the driver's life. Also, if trucks become more autonomous, the most dangerous vehicles on the road (in terms of potential energy) will get immediately safer, especially when considering driver distraction and fatigue as the cause of incidents.

Finally from a UK perspective, level 4 automation will be more effective on whiplash than the government's proposal to deal with the PPI fraud linked to it. It might come earlier too.

Fig 1.14: Impact of ADAS on the insurer's loss ratio



Premiums are not expected to decrease dramatically until 2020 because the percentage of vehicle involved will remain small overall. Also ADAS is first applied to the higher car segments. At levels 3 and 4, we expect premiums will fall in the consumer line. But what is not shown in the graph below is the potential for the leasing/ commercial line as manufacturers have to insure liability of their products.

The figure presents a simplified, birds eye view of impact on claims. From the trends detailed above, it suggest the impact of Level 2 automation will be positive, Level 3 we carry a lot of risk and Level 4 will have strong impacts that will equalise. We consider and quantify the impact on claims and premium in much greater detail in Section IV.

Source: PTOLEMUS

B. The driverless car could destroy more than it creates

From Ford to Uber and from the NHTSA safety requirements to the regulations discussed at state level, the US is clearly preparing for the driverless car in parallel with the level 4 autonomous vehicle. The implications of the two types of Highly Autonomous Vehicles (HAVs) are very different and we analysed them from the perspective of the drivers/users, society and the mobility business.

1. Driverless cars will trade safety and convenience for privacy

Driverless cars will not avoid all collisions, but we will see that they will have a dramatic impact on fatal crashes. The World Health Organisation (WHO) estimates that 1.2 million people are killed in road traffic accidents every year - the equivalent of 5 Boeing 747s falling from the sky with no survivors every day - costing economies between 1% and 3% of their gross national product. These costs are split between:

- Treatment of the people injured and/or rendered disabled by the collisions,
- Dealing with the vehicles involved – replacing or repairing it,
- Reduced productivity and/or working hours of family members associated with the victims,

- Costs of determining the cause of the incidents,
- Cost of road maintenance and other road infrastructure repairs and labour needed after serious accidents.

Aside from saving lives and the various costs attached to these losses, AVs are promised to **give more freedom to people lacking access to personal transportation** because they do not have driving licences. Both the European Parliament and NHTSA consider the assistance to people affected by disability or disease, including elderly people, is a key criteria for the rapid introduction of AVs. It is worth noting these are not the target markets that OEMs or technology providers have mentioned.

Reduced ownership will accelerate driverless vehicle acceptance

Young people are affected too. The growth of shared driverless travel will take place alongside an already growing trend within the millennial to drive less, thereby devaluating the status of owning a car.

Indeed, **car ownership** for the millennial is not seen in the same positive light as their elders. We suggest three reasons for this change of attitude:

- **The inconvenience of driving**, parking and congestion in urban areas make the increasing availability of multi-modal mobility more attractive. They include public transport, ride hailing, peer-to-peer lending, car pooling, car sharing or even short term rental,
- **Costs and complications related to ownership**. Insurance is expensive, plus parking tickets and permits, road tax, servicing, repairs, fuel etc.,
- **Personal communications** makes organising trips easier, between friends or through the multitude of convenient apps.

While it is debatable whether this is a choice from the younger generations or the reality that they cannot afford the costs associated with becoming a vehicle owner, ride-sharing has started to become an effective alternative to ownership.

In the US, **the number of young people with driver licences has been steadily decreasing**. In 1983, 92% of 20 to 24-year-olds had a driver licence. In 2014 it was just 77%. In 1983, 46% of 16-year-olds had a licence. Today it's just 24%. On the whole, millennials are 30% less likely to buy a car than someone from the previous generation.

The impact on privacy will be potentially severe

The "Facebook generation" will probably accept sharing driverless cars more easily, although some will be wary of their implication on privacy.

At level 4, the camera feed from the car may need to be monitored and/or recorded in certain situations. Since they might be driverless, they will need to report a hit and run incidents and protect themselves against theft and vandalism. It is very easy to stop or divert a driverless car, so we can imagine this might enable criminals **quickly hijack the vehicle**.

In turn, the privacy and societal consequences of a vehicle that is constantly roaming the street with cameras looking out and recording have to be considered. Since the level 3 autonomous vehicle will require the driver to be monitored constantly, there will be no escape. This may create a **bad image for the robot cars** that are safe but dumb and taking space on the road.

For these reasons, it is doubtful the driverless car will make a successful appearance in cities or suburbs where crime is an issue. Also we expect the manufacturers will have to **include in the driving behaviour of the vehicle a certain level of assertiveness and authority**.

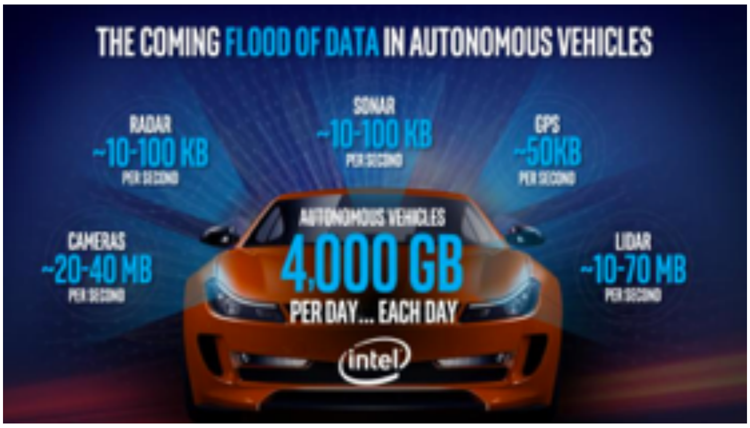
It could be expected that other traffic, pedestrians and cyclists consider them "fair game" – safe enough to **cross in front, forcing cars to brake suddenly.** The driverless vehicle will need to be able to warn a pedestrian not to cross its path. It will also need to be able to call for emergency services if it is broken into, vandalised or hijacked.

In fact, **there is an immediate danger that the introduction of driverless cars may be rejected** because ubiquitous monitoring is not everybody's vision of what progress should cost.

Drivers will be faced with a stark choice: ownership (and liability), or no ownership, no responsibility but also no control and no privacy.

2. *Driverless will affect cities, economies and society as a whole*

The societal changes brought about by driverless cars will affect many facets of how we live. Continuing from the privacy angle, ADAS already generates gigabytes of data, in five years, the Connected Vehicle Trade Association (CVTA) suggested level 3 and then level 4 vehicles will generate **one billion gigabytes of data per year. This would require new regulations, management processes, infrastructure and monetisation rules.**



The issue of data ownership has not been solved in practice. The driver's data is meant to belong to the driver, but **ADAS data goes beyond that**. The data generated is granular and highly sensitive because it is personal, and includes all aspects of the vehicle's usage as well as the behaviour of the people inside.

To date, there are **no coordinated regulations** on what data the OEMs have to share, and none of the OEMs have volunteered any suggestions.

For example, in France, legislation is being developed in response to recent terrorist attacks, which could **give government agencies significantly more access to personal data**. Car manufacturers could be drawn into a scenario where law enforcement agencies demand access to a vehicle's data.

With the current lack of definition on data ownership and the potential to track terrorist activities, OEMs could become embroiled in far reaching **debates about civil liberties** and the role of the state. Evidently, the manufacturers are in no great hurry to have to deal with counter surveillance, incident fault determination or lawsuits related to the private data they collect.

If eCall is anything to go by, then defining a minimum set of data transmitted from the vehicle, the means of transfer and the access to it, could take more than 10 years.

Driverless vehicles could depopulate city centres

At a city management level, cars have been a major contributing factor to the growth and expansion of our urban spaces, but they also have been very detrimental to the city centres. Individual transportation accelerates suburbanisation, segregation and, in some cases, has been the cause of thriving cities' downfalls.

If the driverless car pushes residents from the city centres, this will accelerate the drop in density, which leads to loss of tax revenues, as well as socioeconomic interactions that make cities breathing and creative places.

This will increase pressure on, not only city centres' safety and security, but also on budget. We predict that most if not all level 4 driverless cars will be are electric and therefore **do not – today – pay many of the taxes that urban infrastructures rely on**. This includes congestion charges, road/fuel tax, as well as parking permits and fines.

In order to adapt to increasing electrification, regulations will need to change to ensure "riders "pay their fair share". Road user charging or milage based user fees, currently taking place in **Oregon and California** will soon prove very useful in demonstrating how mileage-based car tax can work to replace a gas tax which will no longer be valid.

Indeed, **owned** highly autonomous vehicles (HAVs) could be used to make many family trips during rush hour. Since they are not shared, **half of those trips would be empty.** The expected 30% gain on parking spaces unused by driverless cars on the road would be negated by the increase in rush hour traffic.

Today, already 75% of vehicles carry only one person (the driver); in the not so distant future we could see half of all vehicles with nobody in them at all, resulting in greater congestion on the roads.

If the future of autonomous vehicles could provide a greener, safer and faster version of what we have today, generating more travel, not less.

Driverless vehicles could also impact public transport

Driverless pods in urban and suburban settings will become a much stronger proposition than buses. They will pick passengers up at their homes and drop them exactly where they want to go. With increasing usage, on-demand ride-hailing will become even cheaper, especially if the fleets allow for on-demand car sharing. In France, public transport operator SNCF already views car pooling provider BlaBlaCar as its largest competitor and has been forced to adapt services as a result.

Without drivers, these electric fleets will be able to service locations **where public transport doesn't make commercial sense**. Several US states have already begun subsidising Uber journeys to compensate for the cancellation of public transport services. Lyft also helped a dozen transit agencies apply for federal grants that would pay for a portion of Lyft fares. The drivers would effectively become part of the local public transportation system. In turn, this will allow more people to move away from densely populated areas without sacrificing the advantages we associate with urban living.

The opportunity for existing mobility services to slowly replace commuting traffic with driverless taxis is significant - another reason why almost every major OEM is rushing to either invest in or launch its own mobility service, as we shall explore further in Section VI.

Once the drivers themselves have gone, the ride will, at first, become more restricted but much cheaper, and in time will cover more of the city, replacing buses, shuttles, trams, school buses; resulting in an army of potentially near-empty cars roaming the streets.

While ***car pooling schemes such as BlaBlaCar, UberPool, OlaShare, Lyft Line and GrabShare have been a tremendous success across the globe***, without the taxi driver, many **people may be reluctant to share** a small, enclosed and private space with strangers. This could reduce the utility of driverless taxis, compared to manned taxis, in the short-term.

Elon Musk suggested that his customers would be able to rent their autonomous cars when otherwise not in use. He never said that two or three people could share the trip. He did, however, indicate that drivers could cross the US in one trip without touching the steering wheel. Owned HAVs will certainly enable longer car journeys; a single driver could cross countries or states overnight with minimal human driving time. This could start having an impact on short haul continental airlines and motels.

The comparison and antagonism between driverless vehicles and transit does not stop here.

The Centre for Transport Studies highlighted in its research the impact of train-like driverless automation on congestion. The study from Imperial College London challenged the popularly held notion that autonomous vehicles will reduce congestion (Cf. the case study below).

More recently, we saw the first "official" protests and calls for driverless cars to be banned for 50 years.

The call by the **Upstate Transportation Association** - a lobbying group for taxis in New York - is the first backlash against the concept of driverless cars. It is based on the fact that if Uber and Lyft are now made available in upstate New York, the promised 13,000 jobs creation will never materialise.

CASE STUDY
Centre for Transport Studies research on traffic

A study conducted by the Centre for Transport Studies at Imperial College London challenges the popularly held notion that autonomous vehicles will reduce congestion.

The study assessed the trade-offs involved in increasing comfort and reducing congestion as a result of having more autonomous vehicles on the road.

The potential comfort of an autonomous vehicle was equated to the comfort of a train, where moderate, smooth braking and acceleration are essential factors to creating comfort and facilitating productivity. The study simulated what effect, smoother acceleration and braking by passenger vehicles would have at an intersection.

The study begins by simulating a four-way intersection, where 25% of the vehicles were driverless and all others were standard vehicles. Some driverless vehicles simulated the acceleration of light rail (moderate comfort) and others simulated high-speed rail (extremely smooth). 16 scenarios were modelled where smoothness was improved or speed reduced and tested against the baseline with all standard vehicles at the same intersection.

In every test scenario, driverless cars designed to increase comfort made congestion worse.

In the baseline scenario, vehicles experience an average of a 20 second delay at the intersection. In the light rail scenario, congestion worsened anywhere from 4% to 50% (21- 30 seconds). In the extreme comfort scenario, congestion increased anywhere from 36% (27 seconds) to 2,000% (6 minutes and 44 seconds).

The study concludes that if we want to experience higher levels of comfort in autonomous vehicles, we may have to make concession in congestion levels.

The study was not intended to abolish the idea that congestion levels can be reduced by autonomous vehicles, but to highlight the potential engineering and design challenges facing OEMs and urban planners.

All these are real scenarios that **could make the prospect of driverless car as appealing as GM food**. Of course, like mobile phones or the iPad, which were widely discredited before arriving on the market, autonomous vehicles – including driverless ones, have a chance to be well accepted and bring a positive influence on society.

Shared driverless vehicles will likely be accepted if they appear **slowly** as part of a trusted mobility brand, and together with sufficient education and positive PR. They will evolve alongside level 3 autonomous cars that rely on a driver but are safer and progressively more in tune with the rest of the traffic flow.

Shared driverless cars could operate **as part of a wider set of mobility tools** and could cost as much as public transport – and be paid for in the same way - yet provide a door to door service.

There are critical benefits to driverless vehicles. A paper from the MIT recently suggested that the mobility demand of a city such as Singapore could be met with **only 30% of the vehicles** on its roads today, thanks to a publicly accessible fleet of HAVs.

That number would be cut by a further 40% if all commuters on a similar route agreed to **share vehicles**. Additionally, 30% of the traffic in cities today is caused by people looking for a parking space.

ZipCar CEO Robin Chase suggested car sharing reduces the need for parking and that ride sharing reduces congestion. Combining the two would be ideal but totally dependent on people's willingness to share cars. We expect the pick-up rate of **car sharing will accelerate rapidly as soon as level 3 automation vehicles are used** in fleets and advertised as such. However, we don't expect the share of vehicle trips made using shared cars will exceed 30% at best.

Advances in tolling mechanisms can also help **regulate and charge peak traffic** as well as **penalise "Zombie cars",** and in this way generate revenues to finance infrastructure maintenance.

To make automation work, it will be essential that it happens progressively.

We have analysed and quantified the return on investment for the driver at levels 2, 3 and 4 of automation in Section II of the study.

3. From the perspective of the mobility industry, things are rather different

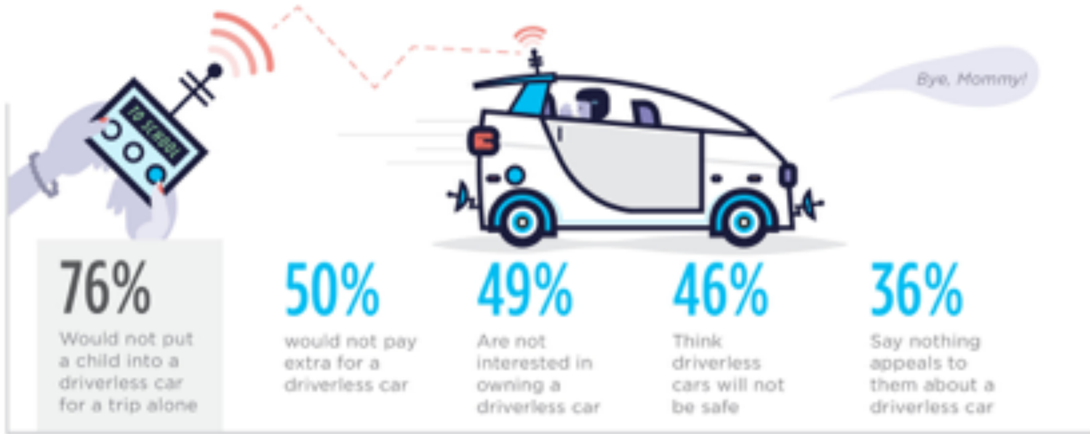
A safer, easier way to drive vehicle is always welcomed, but, to date, the concept of driverless vehicles has not been well received.

This result from a **NerdWallet survey of 1,000 US citizens** demonstrates how the introduction speed of the driverless vehicle could derail it from the start. For example, it is far too early for people to start embracing the idea of sending the children to school in a driverless car.

Driverless vehicle ownership is unclear and the value proposition has simply not yet been communicated. For drivers enjoying their vehicles, **the word "driverless" is unattractive,** and taken out of context provokes negative reactions.

This is very similar to, for example, survey results from Progressive Insurance, which suggest 40% of the driving population would never consider using an OBD dongle to tell their insurer how they drive.

Fig 1.15: The public's expectation and understanding of driverless cars are not in line with the supply



Source: NerdWallet

OEMs and mobility companies must take this into consideration once the hype of the driverless trials resumes and the reality of the offer becomes clearer. In the meantime, it is fair to suggest that surveys – and communication on the topic – should not be made on a concept based on one word, but based on a tested and tangible proposition with its advantages and constraints explained.

OEMs themselves might have to think twice about what to promote. Car sharing companies and studies from the University of California suggested that 2% - 5% of the population considered selling one of their cars after they started to use car sharing. **Another 7% - 10% would avoid buying a new car because of car sharing**. This is the case for Car2Go in North America, specifically in cities such as Calgary and Vancouver, where the company has more than 200,000 registered users.

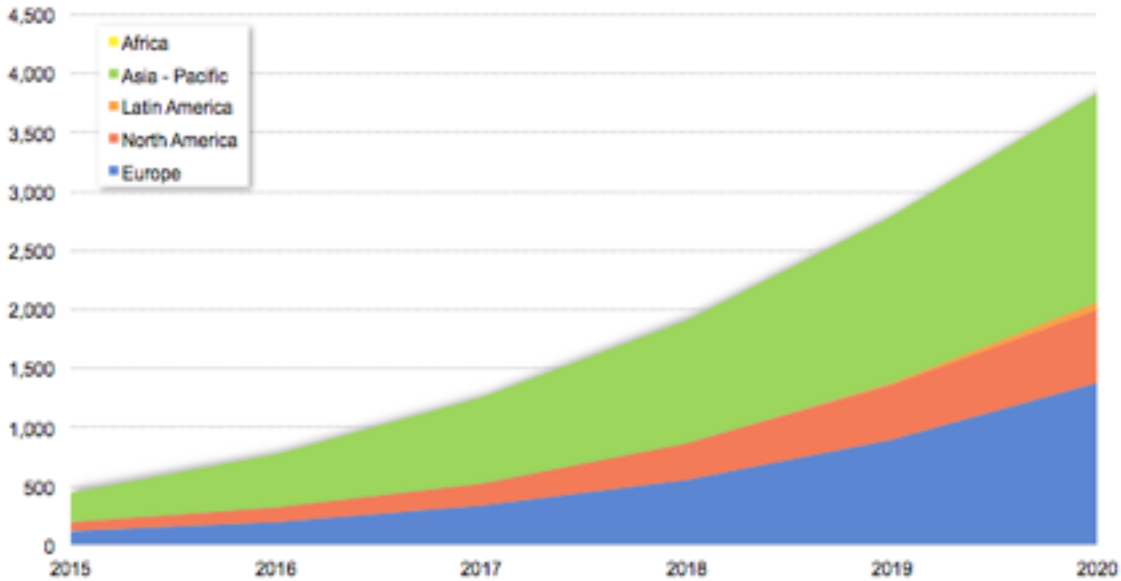
Today, car sharing in the US has been used by 19% of adults, the majority of whom are under 44 and have an average income of around $50K per year according to a study by Roland Berger. The biggest service providers there are Turo and Getaround for the peer-to-peer (P2P) sharing model and ZipCar and Car2Go for the business to consumer (B2C) model.

Globally, we expect car sharing to grow extremely fast alongside vehicle connectivity and automation. The graph below includes P2P sharing schemes, we believe the number of shared cars will reach almost 4 million globally by 2020.

Despite only launching in late 2013, China's two largest P2P sharing platforms, ATzuche and PPzuche already have a combined membership of over 2 million and over 200,000 cars.

France is leading the way in Europe, with its two dominant P2P providers, Ouicar and Drivy, listing over 30,000 cars each.

Fig 1.16: Total number of shared passenger cars in use (thousand)



Source: PTOLEMUS Connected Mobility Forecast - April 2016

Peer-to-peer schemes will become ever more relevant as the general car fleet in each country reaches high levels of automation, thus increasing the ease with which one can share their own car. We explore this concept and how models of car ownership are already changing in further detail in Section VI. More details on the forecast for car sharing and other connected mobility services can be found in our Connected Mobility Forecast .

The ride hailing businesses will also need to change dramatically in order to benefit from this opportunity. Companies such as Uber or Didi Chuxing might save significant amounts on driver costs, but, under the current model, these platforms have no ownership, responsibility or costs concerning the cars themselves. **Uber and Didi pay nothing towards fuel or maintenance costs and insurance premiums are much less** as drivers are typically only covered whilst a passenger is in the car.

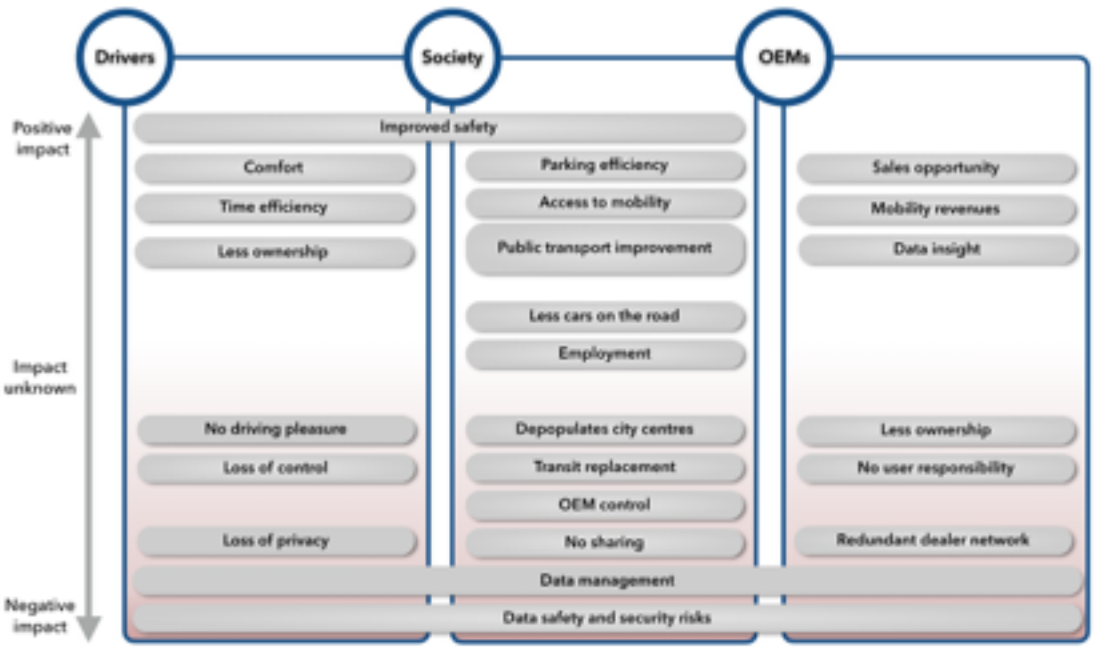
At level 4, the driverless car results in other potential consequences. Since there is no owner-driver, none of the running costs (i.e. road tax, road tolls, parking fees etc.) will be paid by the driver. We estimate that the vast majority of level 4 driverless cars will also be electric, meaning these vehicles will not contribute towards the fuel tax, which remains the primary source of revenue for spending on roads around the world.

As the user's **responsibilities for the vehicle are removed,** so are the social constraints applicable to public transport regarding proper behaviour. If driverless cars are used as private buses, users will have to abide by rules to ensure they are not abused. For this reason, the OEMs and/or mobility companies must plan insurance and liability coverage for passenger behaviour as well as for the vehicle itself.

The majority of insurers we asked think OEMs will take a stake in insuring the drivers directly as soon as the vehicle becomes partly autonomous (level 3). Some of the OEMs openly agreed that, whether the cars are sold directly or shared via a car sharing programme they own - and since the driving data is used to price the risk if the user is driving - OEMs are in the best position to offer the insurance service.

The demand for insurance policies built around vehicle-based telematics has been growing and we expect the variety of policies available to increase. At the same time, the opportunity extends beyond the vehicle data alone. The benefits of augmenting it with car and smartphone data or with public transportation systems information are huge. It would enable the insurer to **switch from insuring a driver to insuring the person's mobility as a whole, irrespective of the transport mode.**

Fig 1.17: Impacts of the L4 driverless car



Source: PTOLEMUS

Lastly, driverless vehicles would deliver the most valuable resource of all to its users: time. Some may use this for infotainment, some may choose to work, some may use the time to take a quick power nap. Either way, driverless cars could begin to reverse the growing trend of time poverty across the Western world. We expect that manufacturers will be keen on monetising car-based access to favourites, content and office functions. We have analysed this in detail in Section II, including the partnerships OEMs have made to build the necessary connected data platforms.

The driverless car trend could be a very successful evolution in transport and service provision and accelerate the natural development of the mobility sector. At the same time, our analysis suggest it is very risky.

Drivers or users could easily lose as well as gain from it and the early signs of acceptance are fairly modest. Car manufacturers have also little to gain from driverless automation, unless of course their role extends to mobility provider, which is the case for many already. If the cars are effectively shared, new car sales will decrease significantly.

The key hurdles across the 3 groups are **privacy** and data management, requiring a common framework, **taxation** and employment rules needing to change and, of course, user behaviour and **expectation** needing to be managed.

In our quantitative analysis (see Section VI), we assess the impact of 3 scenarios on the adoption and volume of autonomous and driverless vehicles.

C. 10 other markets that will be affected by ADAS

1. The commercial vehicle market

The impact on high and light commercial vehicles will be examined in detail in Section II as we analyse earlier platooning tests. While the sector will benefit from ADAS from a safety aspect, the benefits of platooning will depend a lot on the type of journeys and the geographic background. We see that while the Otto/Budweiser truck or self-driving electric delivery vans might make headlines, these are product announcements and PR stunts, not product launches, and certainly not yet trends. The reality is that on the liability front, the cargo will not be left to a machine driver alone. Also, the act of delivery often has to be done by a human, so the impact of **automation may be consigned to assistance in long range trips in the short to medium term.**

2. The insurance & reinsurance markets

The insurance market could change radically. If Mobility-as-a-Service becomes the dominant model, the commercial line would expand, driven by OEM's product liability and by the fleets of Mobility Services Providers (MSPs).

On the other hand, in the long run, personal line motor insurance could become restricted to second-hand vehicles. This would certainly increase industry consolidation in the insurance market as a whole.

Increasing automation will also change the definition of motor insurance covers. We have already seen examples of policies adding coverage for failings related to firmware update. Looking ahead, insurance coverage will also need to account for more expensive - technical - repairs. Glass repair for ADAS-equipped vehicles is already twice more expensive than for "normal" cars.

3. Energy supply

We believe that most level 4 autonomous vehicles will be electric and that their impact on broader society will be combined and advance in parallel.

Supplying enough electricity for the entire car park in the US to run on it would increase the yearly demand by 30% - 40% according to various estimates.

How that energy will be generated is highly contentious. Environment-friendly vehicles could be running on coal-, or even oil-derived electricity! Hardly a step forward.

4. Energy delivery

The whole fuel delivery infrastructure will have to change. Electric and driverless vehicles will remove the need for urban fuel stations as they exist today and ownership of the charging stations will be linked to the fleets themselves. Early step in that direction were announced in the proposed Vehicle Technology and Aviation bill in the UK.

If passed, the bill will

- ensure **data** on charge point location and availability is openly available,
- set **minimum technical specifications** for charge point connectors,
- oblige charge point network operators to allow **interoperability** between networks,
- mandate provision of electric vehicle **infrastructure at motorway** service areas and large fuel retailers,
- require that charge points are 'smart' and can **interact with the electricity grid.**

In effect, the bill would force big **fuel retailers to provide charging access** and parking slots in their forecourts. It would also ensure the public charging points are properly staffed and in working order. Finally it would create a single standard for charging and a single subscription to access the service nationwide.

With "only" 4300 public charging locations, it is the best time to create technology and service standard to accelerate adoption. Creating similar interoperability for tolling technology and services in Europe has been in process for over 15 years and is still far from solved. With **at least four standards operating today** - including Tesla's own- it is urgent national government step in and standardise the delivery. Germany has proposed such restriction proposing all charging points include a CCS connector.

5. Car parts and maintenance

Besides the reduction in collisions requiring repairs, several factors will limit the repair networks future business. Smart driving software, such as brake assists, will **reduce wear-and-tear** on the vehicle, especially electric ones, necessitating fewer replacements. Maintenance on connected vehicles that are not owned by their drivers will be more efficient and also require less workshop time.

Fewer accidents, combined with a growing number of electric vehicles will also foster direct relationships between OEMs and drivers, **again limiting the potential for independent repair networks** who could face losing a significant proportion of their business. On top of that they will need to be equipped with increasingly complex and brand-specific equipment. Replacing new electronic equipments as well as sensors requires access codes and methodologies. These need to be licensed from the OEM.

Some the repairs will also become impossible on the road and will require a workshop visit - a damaging forecast for the third party repair companies that invested in their mobile repair teams. For example, light and humidity sensors that trigger the wipers are embedded in the windshield making it impossible to repair outside a workshop.

CASE STUDY
Glass repairers reorganise on both sides of the Atlantic

The Auto Glass Safety Council in the US has modified the Auto Glass Replacement Safety Standard document in October 2016 in order to develop clear guidelines specifying what conditions are necessary before a technician should replace glass in cases where ADAS recalibration may be required.

As we have seen elsewhere there is a difficult balance between the responsibility to repair sensor-equipped windshields and the cost to do so by independent repairers. The impact on safety is critical and enquires certification. The price of doing the repair increases rapidly - together with its impact on the insurance sector - and with it the responsibility and requirements from the car manufacturers.

As always, getting the OEM approval for repairs is proving increasingly difficult for independent bodyshops. They cannot do without it. Holding to a standard of "OEM-approved" is necessary to prevent possible litigation and liabilities.

For the glass repairers, there are wide differences between OEMs, parts, models and years, which all need to be monitored for change as well as trained and retrained for.

Some windshields with ADAS sensors are straightforward to repair as the camera self re-calibrates. But in the case of Volkswagen for example, it requires parts, complex methodology and tools. Essentially more cost, time and the inability to do the repair at the customers site or on the road side.

In order to continue to provide the - insurance required - roadside service, service providers such as Belron in Europe have had to purchase licensed target boards for calibration as well as the OEM specific codes to reset the camera using an OBD dongle. To get the access to the OEMs codes, they had to partner with Hella Gutmann.

In fact windshields are a central problem for the third party repair networks. ADAS sensors such as cameras are embedded in the windscreen, making repairs difficult and significantly more expensive. Not only can the repair not be done in situ, it also requires specific (licensed) equipment and calibration.

As long as autonomous traffic is mixed with "dumb" cars on the road, there will be accidents. If ADAS equipped cars are hit, the cost of that repair is much higher. We will quantify this change in Section III: 2.

6. Dealership networks

As with all other advancements in the car market, dealers will need to train, evolve and be responsible for educating customers about the new features.

Safety alone rarely sells, only alongside increasingly assisting and desirable driving functions will the dealerships find in ADAS a feature that increases their commission.

Future vehicles will also be connected and upgradeable. Over the air updates are the favoured way to insure all necessary updates are done, they also allow the manufacturers to offer for optional paid-for updates.

For the lower end brands however, using the network will make more sense and also save on the 4G connectivity required. That visit could also be an opportunity for mandatory training. At this stage, closer relationship with insurance partners will increase customer service quality and provide swift repair. We will assess the requirement on training in Section II.

OEMs have been clear that they are considering training. However, most drivers are not interested and they cannot make it compulsory. Only if a regulation is issued or a MOU is in place will they have the capability to enforce training at the point of sale. Another option could be for the insurer to add excess to the insurance unless training has been completed.

7. Car brands and manufacturing

We will likely see the emergence of new independent vehicle manufacturers as the distribution models change. Bolloré, whose initial core business was in the paper and tobacco industries, is a good example of a company that has since moved into vehicle contract manufacturing with PSA, alongside significant investments in electricity storage solutions. This enabled them to win the contract and entirely control the **Autolib** electric car sharing scheme in Paris without vehicle manufacturing facilities of their own. The company has also since won the tender to operate a brand new fully electric car sharing scheme in Singapore, which will consist of 1,000 vehicles. Bolloré has also seen strong growth in the highly competitive US market, where many traditional OEMs, who are otherwise leaders in car sharing and mobility services have struggled.

8. Vehicle manufacturing supply chain

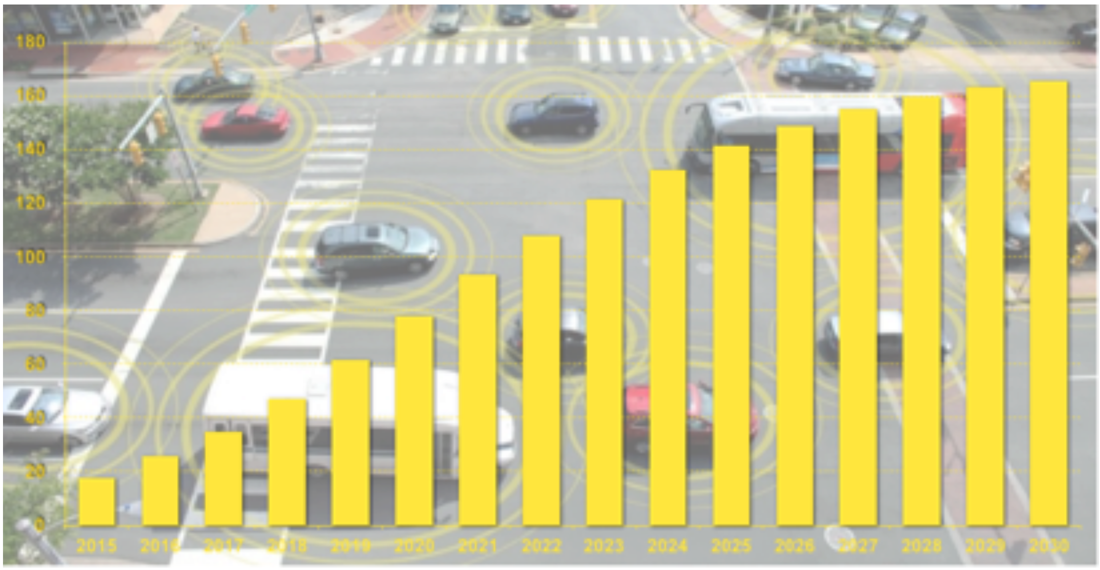
Over the next 15 years, the share of electronic components and technology as a proportion of the total vehicle build cost will continue to grow dramatically. At the same time, traditional part manufacturers will face competition from more technology-focused companies such as Nvidia, which has already partnered with several automakers to help build decision-making driving computers. Cf. Section VI for more details.

9. Mobile telecommunications

We expect the growth of connected vehicles will mean that, in Europe alone, 7 times more vehicles will be connected in 2025 than today (Cf. figure below). At the same time, connectivity will not be used for entertainment only, it will be required to send heavier data packets including insurance information, images and video.

The demand on wireless data flowing to and from the vehicle and the number of connected vehicles will put pressure on the sometimes already saturated wireless networks. At the same time the volume increase will help location-based content and advertising providers and accelerate the demand for fast wireless data connectivity on motorways.

Fig 1.18: Passenger cars with embedded connectivity in Europe (million)



Source: PTOLEMUS Connected Mobility Forecast

10. Driving schools

Driving is already in decline. A study from the University of Michigan showed that just 69% of 19 year olds had a driving licence in 2014, compared to 87.3% in 1983. The study further shows that the share of people with a licence has decreased across all are groups between 2011 - 2014 alone. In Europe, the level of car registrations today is once again increasing slightly following the economic depression, but is still 20% lower than what is was in 2007.

In cities, driving is also decreasing. In the past 20 years, the population of London has grown by almost 2 million, yet car use has held steady at about 10 million trips a day. This is mainly because London has invested in public transport while refusing to increase road capacity. The result is a marked decline in the share of journeys by car, from 50 per cent of all trips in 1990 to 37 per cent currently.

Ownership is also declining as congestion and environmental factors make owning a car more attractive. We expect that the **global number of vehicles on the road will stop growing by 2028**.

We are also expecting specific licences will be required to use autonomous vehicles. On one hand, **more training** will be needed and a different type of driving behaviour will be required at level 3 automation where the user is expected to hold off the wheel but at the same time stay completely in charge of the vehicle.

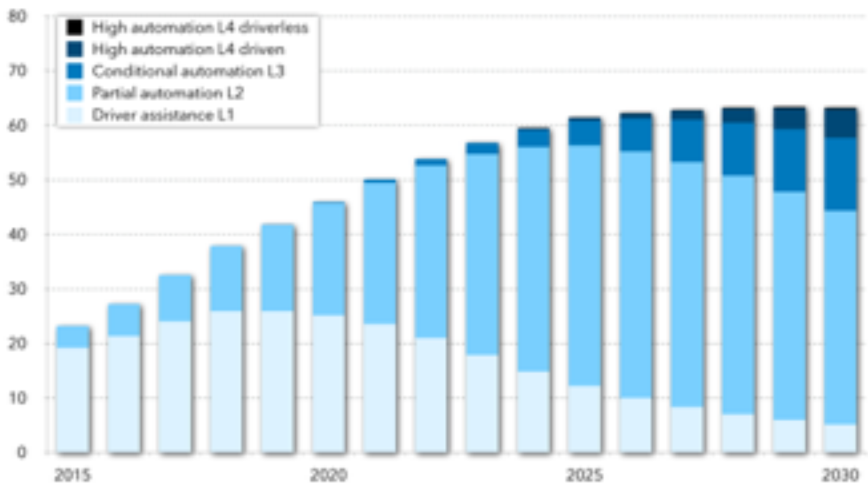
On the other hand, **limited licences** to use a highly autonomous vehicle will need to be considered to allow different segments of previously unauthorised groups to be alone at the wheel, including the underage, disabled and elderly.

D. Overall AVs will have a positive impact

Based on the trends in the market described above and the full research available in the study, we expect most new cars in the US and Europe after 2018 to have AEB.

As a result level 2 will represent **62% of new car sales in 2030.**

Fig 1.19: New passenger car sales worldwide (million) - mutually exclusive categories



Source: PTOLEMUS

By 2030, **HAVs (L4) will represent 8%** of new car sales, adding up to more than 5.5 million units but still amounting to **only 3% of the cars on the road.**

As a result, we estimate that for example in the US, over 750,000 crashes will be avoided *every year*.

Overall, while **China** is expected to be the largest market for L1 and L2 cars in volume, the **USA** will still lead for L3 and L4 cars**.** The US and UK are expected to be the earliest market for L4, but volumes will stay low and initially restricted to driverless vehicles in mobility schemes.

Full quantitative analysis by country and region - but also by car class and automation level - is **available in the full study**. The market forecast outputs are available alongside as an Excel file.

E. Alongside the ADAS evolution, electric vehicles will emerge

Following Tesla's lead, all the top OEMs worldwide have been pressed to announce their Electric Vehicle (EV) strategy. Many have been less than enthusiastic about the prospect of abandoning there combustion engine and the maintenance and parts sales that comes with it, but Tesla, although still losing money, has shown there is a clear appetite for a mass market electric vehicle. To a lesser extent, it could also be said that the Volkswagen emissions scandal has made it somewhat more difficult to sell diesel vehicles.

As a result, hybrids and EVs are becoming more prevalent as cities favour them and continue to tax combustion engine vehicles away from their centre.

OEMs strategies can be divided in 3 types:

- Not investing or slowing down and waiting for the AV to launch everything together (BMW),
- Investing step by step, beginning with the electrification of existing vehicles while announcing new electric vehicle/plug-in hybrids for 2020 (Ford, GM, VW),
- Fighting Tesla head-on and catching up at the same time on both autonomous and electric vehicle development (Daimler, Volvo).

Why EV evolution will accelerate AV growth

The 2 evolutions are not only running in parallel because of trends and environmental issues. **Electric engines are run at a cooler temperature and produce a lot less vibrations** than a combustion engine. When an autonomous vehicle is put on the road, it will be expected to run a very complex set of calculations requiring heavy processing power. Today's processing technology works much better at low temperatures.

Also, the German parliament have recently suggested banning **combustion engine vehicles by 2030**. If electric vehicles are the future, it makes sense to plan building them at the same time as autonomous ones.

We have seen that autonomous vehicle deployment will have a very influential role in accelerating car sharing and vice versa. **Electrification will also promote car sharing**. The use case of car sharing and electric cars in urban settings is much more attractive as it can help to eliminate the "**range anxiety**", which often accompanies electric models.

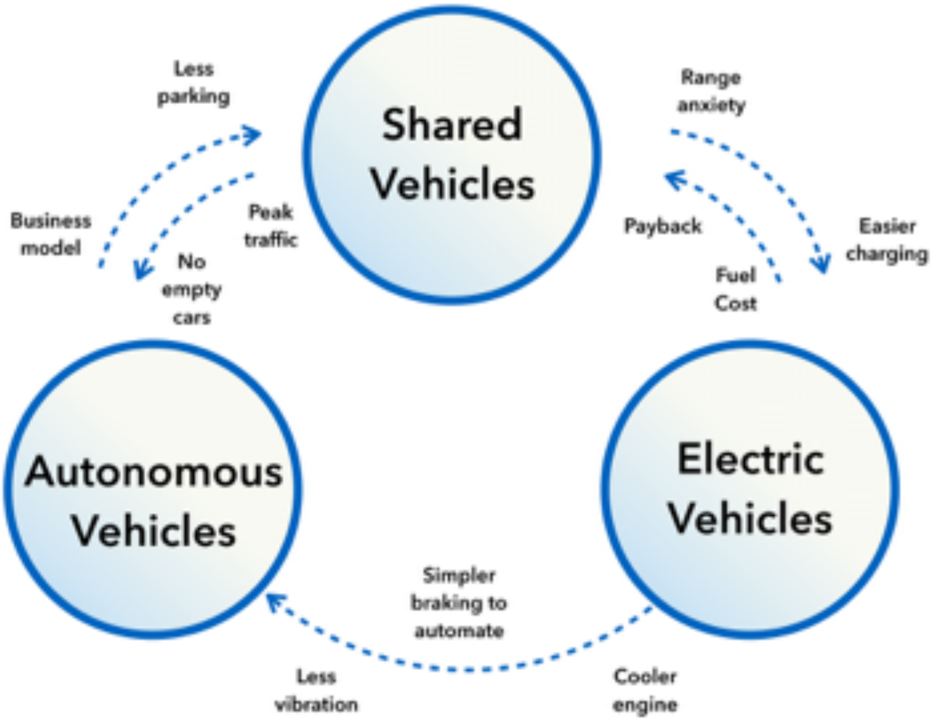
At level 4, shared driverless cars will benefit from being electric as the **payback** will be faster from increased usage and lower operating costs. However, payback will need to be modelled with time as EV batteries gradually lose their energy storage capacity due to time, temperature, average state of charge, the number and depth of recharge cycles, and other factors. Also, EVs driven in hot countries tend to lose their storage abilities faster.

Shared **charging infrastructure** will accelerate the benefits of car sharing compared to having to charge the car at home.

Faster **depreciation** due to higher use-rates will be counterbalanced by lower fuel costs and potential car sharing revenues.

We have illustrated below the symbiosis between the three concepts.

Fig 1.20: How car sharing, electrification and automation promote each other



Source: PTOLEMUS

We looked at 6 of the key OEMs and analysed their electrification strategy. In Section III, we have reviewed their strategies in greater detail, alongside their plans for electric and autonomous cars.

BMW

The i3 only sold a disappointing 25,000 units globally in 2015. Perhaps as a direct result, perhaps as part of a pre-existing plan, BMW announced that it was reorganising its R&D department away for the development any new models such as the i3/ i8 and into producing level 4 autonomous and electric vehicles by 2021.

As part of the complete overall of the company's R&D department, BMW is hiring experts in machine learning and artificial intelligence. It is also integrating the functions of existing computer-driven assistance systems like cruise control, emergency braking, lane-keeping support and automatic parking.

Alongside these developments and far less publicised, BMW has re-launched its mobility platform in the US, ReachNow, integrating numerous new features, including ride hailing and fleet sharing, alongside the existing car sharing service. This will ultimately bring BMW into direct competition with Uber, Lyft and others if the model is extended to other countries. Electric vehicles will feature heavily.

BMW set itself the ambitious goal of having 1 million electric vehicles on the road by the year 2020 or between 15% - 25% of its sales by 2025. In the meantime, updates to the electric models would improve its range to 480 km, bringing it into direct competition with Tesla.

Daimler

Daimler announced it will increase spending in research and development, to "significantly above" last year's €6.6 billion, which was already a step up from €5.7 billion invested in 2014.

It was expected to launch in September 2016, 2 fully electric SUVs and sedans under a sub-brand. The company announced EQ the new brand from Daimler representing "Electric Intelligence", as a concept car with the promise of a system output of 300 kW thanks to scalable battery components suggesting a range of 500 km.

Daimler had its first foray into electric vehicles when it partnered with Tesla to equip the B-Class with an electric engine. The company loosened the relationship in October 2014, selling its 4% stake for about $780 million.

Ford

Like GM and many others, Ford's CEO, Mark Fields also made announcement on new Tesla-beating models being prepared, but, crucially, has not given any dates.

Like Mercedes, Ford only has electric versions of some of its car models on the market today; the Ford Focus Electric Plus, comes standard with fast-charge capability, enabling 75 miles from a 30 minute fast charge (115 miles at full charge) of the 34 kWh engine.

However, there have been reports that the EV only sold only in few states, with sales limited to 7,000, compared to 100,000 Nissan Leafs, the top seller in the range.

The Ford Fusion Energi and C-Max Energy are similarly an adaptation of the original vehicle but with hybrid and plug-in hybrid options. The Fusion hybrid has a 21 mile range on pure electric power from its 7.6 kWh lithium-ion battery.

General Motors

The company is relying on electronics giant LG for its electrification strategy. LG has been mass-producing and supplying the key components and systems such as driving motors and inverter battery packs for the ***Chevrolet Bolt EV***.

The 200-mile electric car, base-priced at $37,500 before incentives, is expected to be launched early 2017 - ahead of the Tesla 3. In pre-production since early 2016, the second-generation Chevrolet Volt plug-in hybrid has only been offered in 11 electric-car-friendly states.

GM is already selling an hybrid equivalent. Dealers are already listing the upcoming 2017 ***Chevrolet Volt plug-in hybrid***, and GM recently announced its first incentives for the new model year. GM is currently offering $1,000 cash back on the 2017 Volt, according to CarsDirect. The Volt sold 2,191 units in October 2016.

The company said last month that through 2020 it will announce more than 10 plug-in electrified "new energy vehicles" (NEVs) plus hybrids, out of over 60 new and refreshed models in an overarching growth plan.

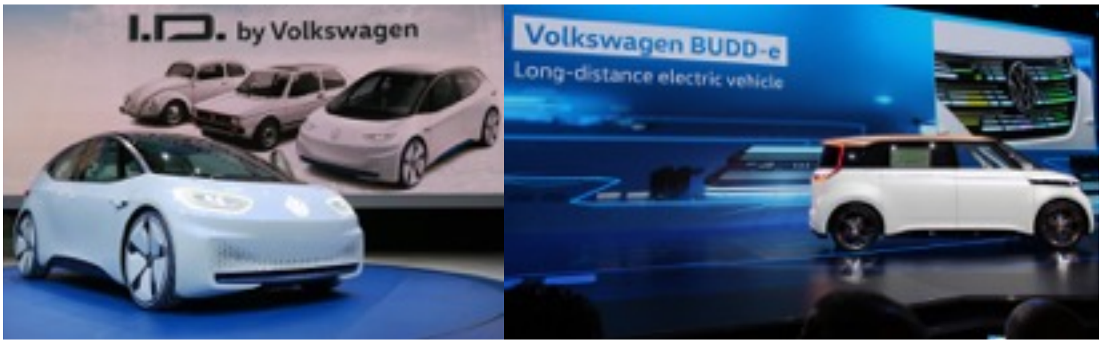
Volkswagen

The group does not have electric vehicles on the market today. Audi's first entry in the all-electric market is expected to be the Quattro in 2018, while Porsche has the Mission E planned for the end of the decade.

Volkswagen announced a compact EV by 2020 and is the only OEM mentioning volume forecast. Its CEO said that the group is putting together a new manufacturing plant that will enable them to produce "2 to 3 million all-electric cars a year by 2025".

CEO Matthias Müller has also changed his tone, switching from all-electric and plug-in hybrids, to only all-electric and promised that "more than 30 new models" will all be "purely battery-powered electric vehicles (BEVs)" by 2025.

While there has been some confusion over the link between the their I.D. electronic concept vehicle and the level of automation included, their plans for the Budd-e microbus are far more clear. With a proposed 331 mile range, enabled by a 92.4 kilowatt-hour battery pack, the Budd-e concept is intrinsically linked to level 4 automation and the groups' new mobility platform, MOIA.



Volvo

Volvo's board has been clear on how they see electric cars moving away from being a niche area to becoming mainstream. It suggested hybrid electric cars will represent 10% of its global sales by 2017 but only expected an all-electric model by 2019. The full vehicle range will later include cars of various sizes which combine an electric motor powering the rear wheels with a petrol engine driving the front. A proposed partnership with LG was touted to be an important factor in this strategy.

A full review of 14 OEMs can be found in Section III but it is already obvious that **the race for EVs and the race for AVs will happen alongside each other**. As much in the engineering room as on the public relations front, manufacturers are clearly seeing a tangible target to attain before their competitor.

When was the last time we saw the car market changing so much so fast? In the last 50 years, cars have evolved only on fuel efficiency (outside the US) and safety. In the next 5 years they are set to be completely redesigned: powertrain, usability, HMI, sales channels and ownership models.

3. The key technologies involved and their evolution

A. Passive to active to ADAS safety systems

Vehicle safety systems are classified into 2 categories: passive safety systems and active safety systems.

Passive safety systems are the ones that help to protect occupants during a crash such as airbags, seatbelt and reinforced body structures. Safety features like these reduce the risk of serious injury and allow drivers and passengers to ride out a crash.

Despite the classification of these features as "passive", they are extremely important when it comes to reducing the severity of crash injuries.

These features are also constantly being developed and refined. For example, in many new vehicles, **airbags** do not just inflate out of the steering column but also appear along the side-panels and even around the knees. **Advanced seatbelt** can moderate the amount of tension across a person's body, so as to reduce instances of seatbelt-related injuries. Even **headrests** can include passive safety technology in order to reduce the risk of whiplash.

Active safety systems are called as such because they do not require the drivers' input ion their operation. Their roles include preventing crash or at least in minimising its impact. Traditionally, there have been many driving assistance systems (DAS) such as:

- **Electronic Stability Controls** improve vehicle stability by detecting and minimising the loss of traction,
- **Post-collision braking systems** use electronic stability control and operate brake pedals when a crash is detected thus reducing the risk of dangerous secondary collisions and minimising injuries and damage,
- **Digital tachographs** record the driving time, breaks, rest periods as well as periods of other work activities undertaken by a driver to avoid dangers related to fatigue and speeding,
- **Event Data Recorders (EDRs)** record certain information from a vehicle immediately before and/or during most serious crashes.

Some of these systems are also gaining global acceptance following regulation by governmental bodies such as NHTSA and NCAP but they are by no means available everywhere today.

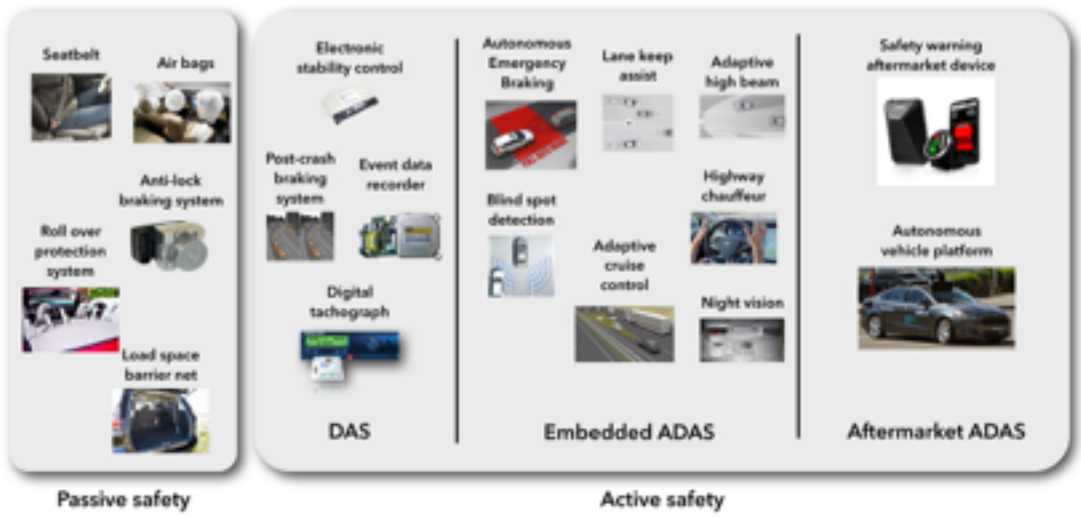
B. Upfitted and embedded safety systems

More advanced systems have now been developed to assist the driver and help avoid incidents. These ADAS systems are classified into 2 groups:

- **Embedded ADAS systems** that are integrated inside a vehicle during the vehicle production phase,
- **Aftermarket ADAS systems** are devices added to the vehicle after production either as "**safety warning only**" to provide notifications in case of danger in the form of display/ audio alerts,
- Alternatively, they could be an "**autonomous vehicle platform**" provided by a tier-1 supplier to a car manufacturer to transform an existing vehicle model into the autonomous equivalent. Such strategy has the potential to accelerate the penetration of automated vehicles because many OEM can share the same platform testing process. On the other hand, for the regulators, having "standard" autonomous platform will make benchmarking and regulating easier.

ADAS systems such as cruise control, forward collision warning and parking assistance have been on the market since the early 2000s. However, it is not until recently that these systems have been powered with greater functionalities and controls.

Fig 1.21: The 2 categories of safety technologies



Source: PTOLEMUS. Note: DAS stands from Driver Assistance System

Forward collision warning systems and automatic emergency braking systems that were earlier restricted to detecting a crash with a vehicle have now gained features to even detect smaller objects such as pedestrians and cyclists.

Adaptive cruise control systems are packaged with lateral guidance components such as lane keeping assist and lane departure warning systems to provide advanced capabilities.

support for driving in a traffic jam situation.

Parking assistance systems have also seen some recent developments. From parking aid systems that monitor the close-up area in the front of and/or behind the vehicle and provides a proximity-based acoustic warnings to parking assist systems that guides the vehicle directly into the parking spot. All the driver has to do is manage the brake, accelerator and shift gears. The steering is handled by the system.

Vision systems have become more sophisticated by not only providing better visibility in poor/night conditions but by also detecting pedestrians and other smaller objects. One of the biggest challenges of driving at night is seeing people walking on the road ahead. While headlights often provide enough brightness to drive safely during the night, objects at distances farther than 40 meters are usually not seen by a driver. At night, reduced visibility puts pedestrians at risk. Night vision systems will warn the driver if a pedestrian is present in the danger zone in front of the vehicle. The width and length of the danger-zone are dynamic and depend on the speed of the vehicle.

Other recent developments include **vital sign monitoring systems** that provide additional safety by monitoring driver's steering, drowsiness situation and other behavioural factors to avoid dangerous situations by providing warning messages in time.

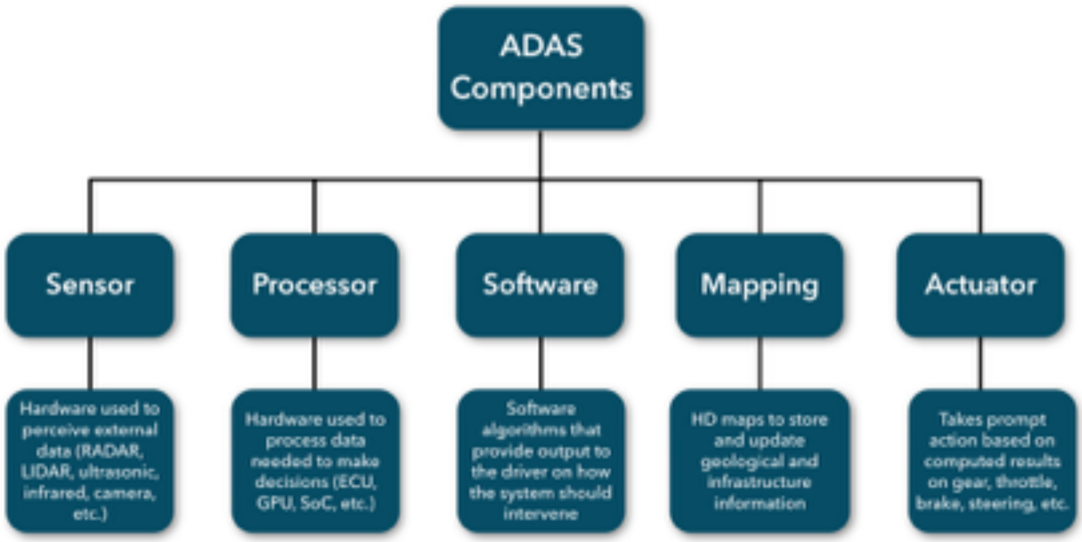
The systems mentioned above assume that the driver is in control of the car for most of the time but will provide assistance or emergency capabilities. But, the next step is to make the vehicle drive itself (hands-off the steering wheel), under specific situations, with the driver being a necessary requirement for regular monitoring. This is where highway chauffeur and remote garage parking systems come into the picture. Although these systems have been developed only recently, in 2016, they are seeing continuous improvements and getting ready to be able to work even in low speed and highly complex situations like city driving.

C. The building blocks of ADAS

All these advancements have been a result of evolution in hardware and software technologies that help in sensing the environment, analysing the situations and eventually directing a system to take prompt action in a critical situation. At their core, the safety systems follow the same general architecture.

The following figure represents 5 necessary **technological building blocs** of ADAS systems. They include 2 key hardware devices: sensors and processors. **Sensors** are used to perceive external environmental information and **processors** help in processing the data collected by the sensors in order to make appropriate decisions.

Fig 1.22: The 5 necessary technological components of ADAS systems



Source: PTOLEMUS

Then, **software** algorithms are used to analyse the data and provide output to the driver on how the systems should intervene. **Mapping** technologies act as an additional sensor that perceives geographical and infrastructural information around a vehicle. **Actuators** such as brakes, steering wheel, gear throttle, etc. then take prompt action on the computed results. Autonomous vehicles will include a separate building bloc: the **machine driver** which combines and integrate the other elements inputs and controls the actuators.

We look in details at each of the building blocks and their supply chain in Section V.

D. The 12 gates left to cross before cars are automated

In this first section, we have seen that the car market is facing a huge storm from which it will come out unrecognisable. We grouped the challenges facing the stakeholders into 12 gates that must be passed in order for autonomous vehicle to happen successfully:

- **Pre-market approval:** Defining the definition is probably the most difficult part of starting an industry. While the US market is self certified, all others are subject to the UNECE safety requirements either directly or indirectly,
- **Technology requirements:** The technical problems left to solve are numerous and can be seen at various levels. **At low level,** issues such as laser obstruction or adverse weather conditions will affect sensors in different ways meaning redundancy systems need to be put in place to respond to *any* eventuality. Since the possibilities that something goes wrong are infinite, the problem is impossible to solve, as such,
- **AI driver's risk profile:** At high level, the future machine driver will need to behave like a human, understand other drivers intentions and take assertive decisions. How will that compare to a human driver in terms of safety?
- **Customer acceptance:** Alongside the excitement and the hype, trust will need to be considered, training for the drivers but also education of the pedestrians and other drivers. Managing rapid change is never easy,
- **Market entry strategies:** This is not just a market demand, price, timing and channel issue. The impact of automation will be felt right across the motor sector. Timing and speed of introduction need to be thought through from the very beginning,
- **In-Car connected services:** Telematics used to be about assisting and entertaining the driver, now connected services have the opportunity to address new opportunities in driverless cars. At the same time the connected, electric, shared and autonomous vehicle will change the face of mobility. Who will manage that?
- **Re-engagement:** This refers to the handover from the vehicle to the driver in the case where the autonomous system is facing a situation or driving conditions that are outside its operating design domain. Several issues need to be solved including what happens if the driver does not take back control, how long is given to the driver to do so and who is liable in case an incident takes place during that gap,
- **Traffic rules and regulations:** Each government is trying to attract research and investment, at the same time a lot need to be done to make autonomous vehicle road legal. With highway code sometimes changing between regions of the same countries, regulators need to act decisively and fast,
- **Car data sharing:** One of the most thorny issues will be to decide what data needs to be shared by OEMs, with whom and in what circumstances,

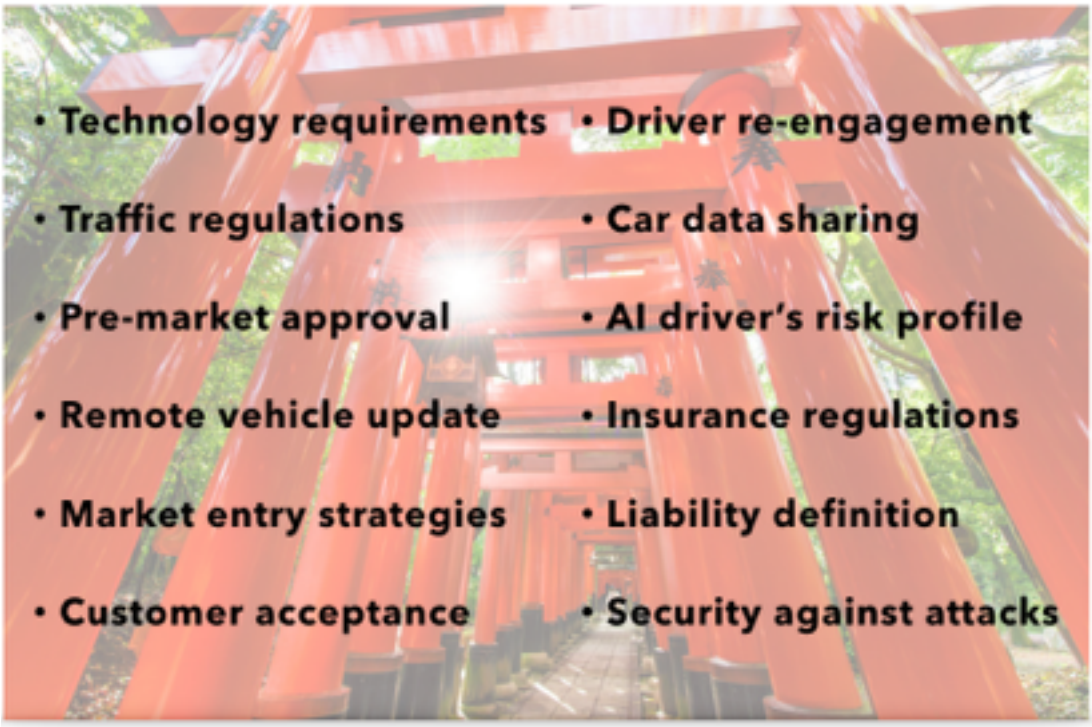
- **Insurance regulations:** Different levels of insurance may be required at different levels of automation, asking the question of who will provide driver/user coverage for different types of incident. A change in the relationship between OEMs and insurers may be required. These are only a sample of the issues this study will look at,

- **Liability definition:** What degree of liability will be covered by whom and at what level of automation will be a key question for all OEMs, mobility providers and, potentially, suppliers,

- **Security against attacks:** There has never been a cyber attack on a vehicle before. There has never been a connected car before with driving function connected to the cloud either. Once and if the vehicle's core functions are using or depending on external data, then the risk that this connection can be compromised will need to be addressed.

These are the 12 gates towards automation and each will be covered, in detail, throughout the study.

Fig 1.23: The 12 gates to automation



Source: PTOLEMUS

This is the end of the Autonomous Vehicle Global Study's abstract.

The full 600-page report includes the following sections.

II. LEARNINGS FROM THE RESEARCH AND TRIALS

1. The public-funded European projects

2. The biggest spenders in R&D budgets

3. The first steps in commercial vehicle automation

III. HOW AUTOMATION IS CHANGING THE CAR INDUSTRY

1. The evolution of the car-driver relationship

B. Measuring and anticipating customer resistance/ acceptance
C. How autonomous vehicle will manage re-engagement in the future
D. Analysis of the emerging challenges in re-engagement process
E. Assessment of the OEM-Driver communication and the required changes
F. ADAS data management strategy

2. The transition to autonomous driving from the customer perspective

A. The new challenges of buying, selling, and using ADAS
B. Segmenting the ADAS technologies
C. The business case for the customer
D. The business case for the level 4 driverless scenario

3. What can we learn from the Tesla crashes

A. Analysis of the 4 cases
B. Tesla's response
C. Tesla's liability

4. Assessment of the core manufacturers' and suppliers' strategies and the evolving landscape

A. OEM profiles
B. The imminent future for OEMS
C. How the OEMs compare
D. Supplier Profiles
E. The role of technology suppliers in automation
F. Comparing the core suppliers

IV. CALCULATING THE IMPACT OF ADAS ON INSURANCE CLAIMS & PREMIUMS

V. THE ENVIRONMENTAL FACTORS INFLUENCING THE TIMELINE

To read the full study, please visit www.ptolemus.com/driverless

or contact thomas@PTOLEMUS.com