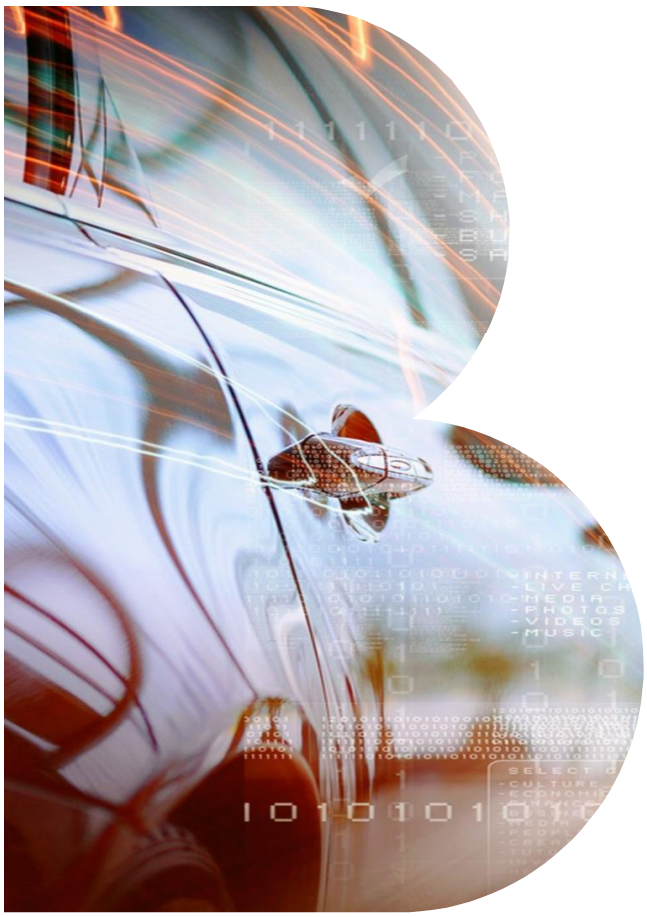


STUDY

Automated Vehicles Index

Q1 2016

Roland Berger GmbH - Automotive Competence Center &
fka Forschungsgesellschaft Kraftfahrwesen Aachen
January 2016

Dear Reader,

In recent months, automated driving has continued to rank highly as a key topic in the German and international automotive press. Tesla's offer of installing autopilot functionality by means of software updates dominated the headlines, yet this was only the first of a series of innovations that are in the pipeline.

This issue of the AV Index provides a comparative update on the competitive positions of individual national automotive industries. The countries' competitive positions have been updated based on the following indicators:

1. Industry: The state of technological development for vehicles designed and produced by the countries' OEMs, plus the scope and focus of corresponding research activities

2. Market: Market size, represented by demand for advanced driver assistance systems as an indicator of user acceptance, alongside an assessment of the legal framework governing the operation of automated vehicles in each country

Roland Berger GmbH and fka Forschungsgesellschaft Kraftfahrwesen mbH Aachen (fka) combine these indicators to produce the quarterly Automated Vehicles Index, which facilitates useful comparison of the competitive positions of the relevant automotive countries (the US, Germany, China, Sweden, the UK, South Korea, France, Italy and Japan), as well as using harmonized global benchmarks to measure these automotive markets against each other.

Besides comparing competitive positions, this and future editions of the AV Index will also take an in-depth look at special focus topics. This issue pans out across current testing/validation methodologies, exploring the need for them and discussing their limits in the context of automated driving. From a development perspective, no other topic is of greater importance to rapid, economical and, above all, safe market launch.

Readers are also given an insight into those automated driving topics that are currently of greatest interest to customers – a subject investigated as part of a recent survey in the US, Germany and China.

Forthcoming issues of the quarterly index will feature a detailed assessment of the legal framework at the European and international levels. This assessment will include a discussion of relevant legislative developments and political factors such as budgetary decisions.

1. Key insights from the Automated Vehicles Index Q1/2016

> **Positioning: Germany out in front – Japan catching up**

The German car industry is successfully defending its role as a pioneer in the development and testing of partially and highly automated vehicle functions. The market launch of new vehicle models (such as the BMW 7 Series) by German premium OEMs is increasing the number and availability of automated driving functions in mass-produced vehicles. At the same time, a number of automotive nations have been cutting Germany's lead. Japanese OEMs have demonstrated a variety of automated driving functions in advanced prototype vehicles – at the Tokyo Motor Show, for instance – thereby improving their relative position in international comparison.

> **Know-how for automated vehicles – Safety a focal aspect**

Compared to the previous edition of the AV Index, there has been little change in the relative knowledge position of the automotive nations examined. The considerable importance of research and development in the field of automated driving to economic policy is reflected in such factors as the spectrum of publicly subsidized research programs announced in recent months. On top of these moves, more and more national and local test facilities for automated and connected driving are being subsidized or started from scratch, especially – but not exclusively – in Germany. Cooperation between automotive OEMs and scientific institutes is likewise being visibly stepped up, with research and development activities singling out the testing of automated driving functions as a focal topic.

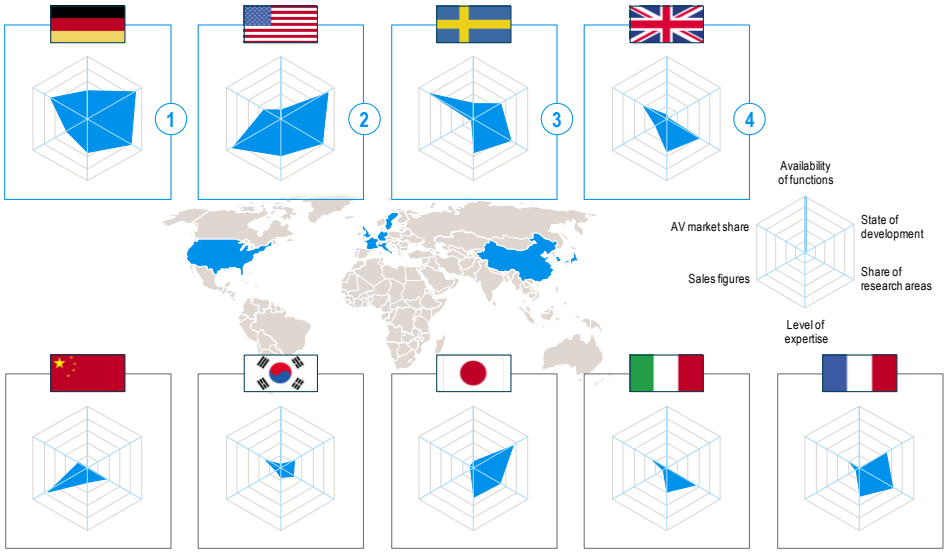
> **Legal frameworks – US has the edge on Germany**

The basic picture of the legal situation has not changed since the last issue of the AV Index. Germany still lags a little way behind the US, due essentially to the simplified licensing procedures that exist in some US states. Notwithstanding, Germany's federal government has in recent weeks and months begun to stake out a legal framework for automated driving. Key action areas have been defined in the government's "Strategy for Automated and Connected Driving" in order to prepare Germany for social, legal and technological challenges ahead.

> **Global market volume – USA ahead of China and Germany**

Measured by the number of vehicles sold that feature relevant advanced driver assistance systems (SAE levels 2+), the US and China are well out in front of Germany in terms of absolute market size. After Sweden and the US, Germany has the largest share of relevant vehicles on its domestic market. However, the US has a clear lead in terms of the number of new vehicles licensed worldwide, followed by China and Germany.

Figure 1: Comparison of the competitive positions of the world's leading automotive nations in the field of Automated Vehicles

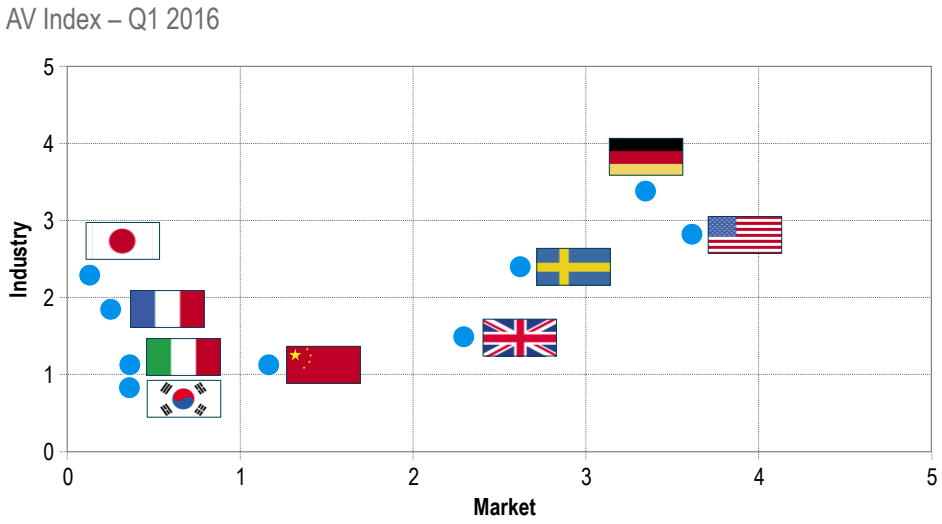


Source: fka, Roland Berger

2. Comparison of the competitive positions of the world's leading automotive nations – summary

Combined analysis of both dimensions – the industry and the market – enables us to produce a visual summary of the competitive positions of the world's leading automotive nations (Fig. 2).

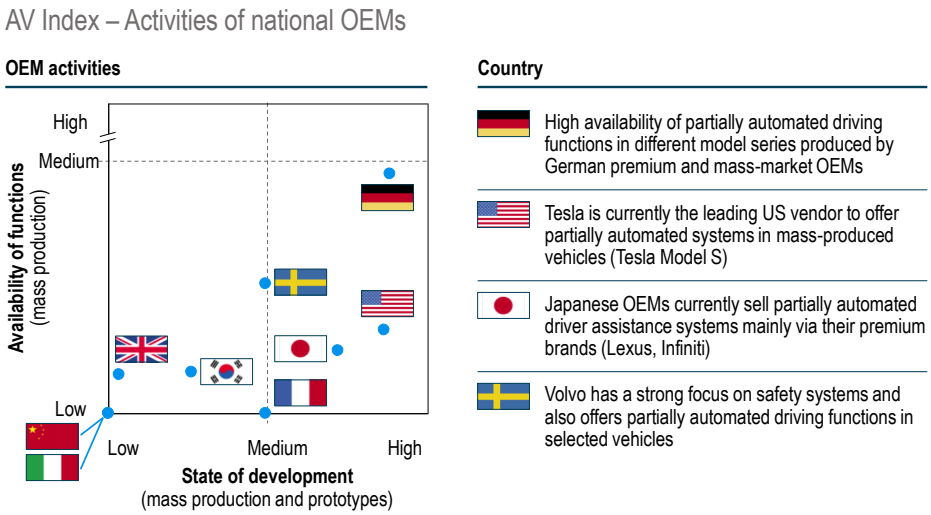
Figure 2: Germany, the US and Sweden continue to lead the AV Index – Japan is catching up in the industry dimension



Source: fka, Roland Berger

Regarding the **industry indicator**, Germany continues to defend its pioneering role ahead of the US and Sweden. This success is mainly due to German OEMs' leading competitive position in advanced driver assistance systems and automated driving functions, all of which are subsumed under the **OEM activities** parameter (Fig. 3). In recent months, German OEMs have launched several new vehicle models on the market, including the BMW 7 Series and the Audi A4. These moves have further increased both the number and availability of automated driving functions in mass-produced cars, with some assistance systems – such as the Emergency Steer Assist system in the Audi A4 – becoming available in executive-range cars for the first time. Since the last issue of the AV Index, US, Japanese and South Korean OEMs have narrowed the gap on Germany. Launch strategies for premium-segment vehicles (such as the Lexus LX, and the Genesis G90) nevertheless place heavy restrictions on the availability of automated driving functions among vehicle models of these OEMs. Tesla is adopting an alternative strategy to improve the availability of relevant functionality in existing vehicles: Its "autopilot" function can be enabled by paying for a software update to vehicles in the field that are fitted with the right sensors. Regarding the state of development of prototype vehicles, Germany and USA are on a comparable level, although the activities of Google and Uber in the US are focused more strongly on inner-city applications. In this area, too, Japan has improved its position thanks to indigenous OEMs demonstrating an array of automated driving functions in advanced prototype vehicles at the Tokyo Motor Show, for example.

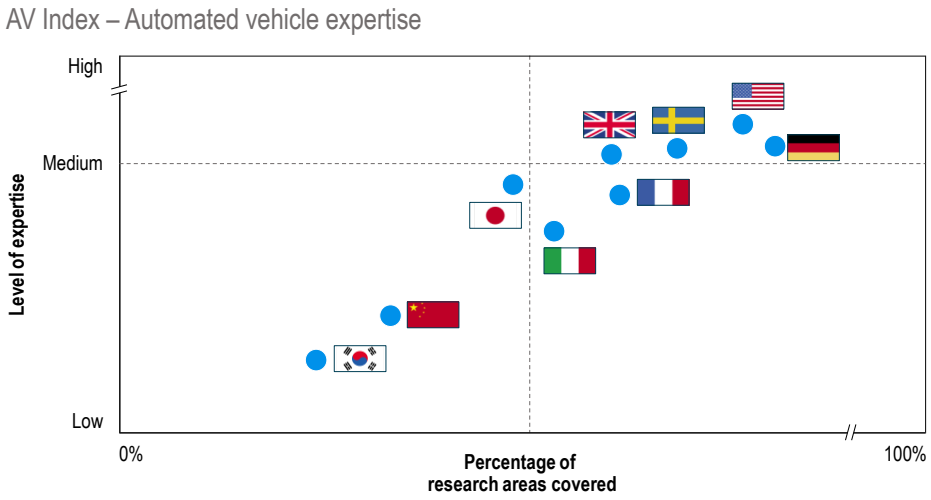
Figure 3: German automotive OEMs have the most extensive range of partially automated driving functions across all segments



Source: fka, Roland Berger

Little change in our assessment of the **expertise** parameter (Fig. 4) since the previous issue of the AV Index means that the relative positions of the analyzed automotive nations remain the same on this score. The extensive research and development activities conducted by top American and German universities are the reason why the US and Germany lead the field for this parameter. Both countries also enjoy intensive scientific collaboration between automotive OEMs and universities in the form of bilateral research projects. Examples include Toyota's announcement of a research center to be set up in cooperation with Stanford University and the MIT (project volume: approx. USD 50 million) and Ford's activities to test autonomous vehicles at the MCity test facility in conjunction with the University of Michigan. Exactly how important research and development in the field of automated driving is to economic policy is further reflected in such factors as the spectrum of publicly subsidized research programs announced in recent months. In Germany, several government agencies like the Federal Ministry for Economic Affairs and Energy (BMWi) are currently backing various large-scale automated driving projects, one example being the Ko-HAF project for cooperative highly automated driving. At the same time, more and more national and local test facilities for automated and connected driving are being subsidized or even started from scratch. To take just two examples: Subsidies have been set aside for test facilities and pilot projects for automated vehicles in the UK (totaling GBP 10 million) and in Germany (e.g. in Aachen, investment volume € 28 million).

Figure 4: R&D activities at the top universities and research institutes underpin the leading expertise possessed by Germany and the US

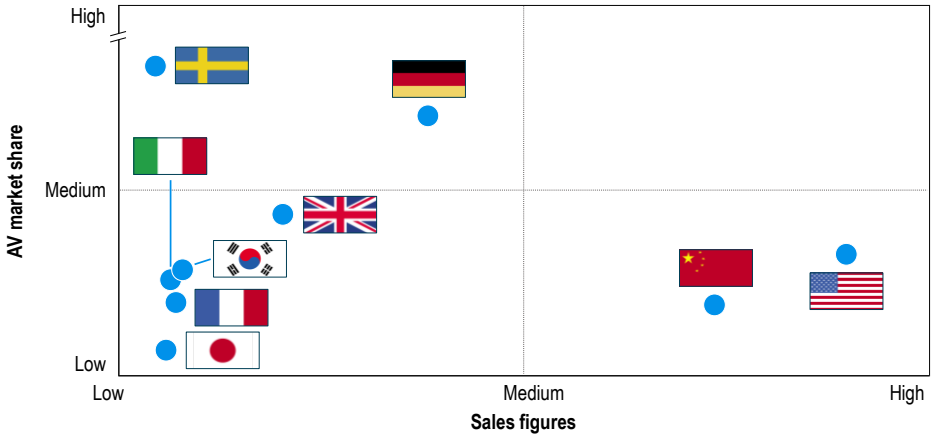


Source: fka, Roland Berger

For the **market** indicator, the distribution of leading positions between the US, Germany and Sweden remains unchanged (Fig. 5). As ever, the US's pole position is favored by a very large market volume (in absolute terms) for vehicles fitted with relevant assistance systems. For its part, Germany has access to a very high specific share of commercial vehicles fitted with such systems. This fact, together with the absolute size of the German market, is enough to give it second place. Despite its comparatively small overall market, Sweden ranks third thanks to the highest proportion of ADAS-capable vehicles. Only the UK, in fourth place, remains within striking distance of the leading group. All other countries share the stragglers' positions.

Figure 5: The US and China have the highest AV sales figures – Sweden and Germany have the largest market shares

AV Index – Market potential for vehicles with advanced driver assistance systems[1)], Q1 2015 through Q4 2015



1) Theoretical market ceiling for vehicles with ADAS fitted as standard or as optional extras

Source: IHS, fka, Roland Berger

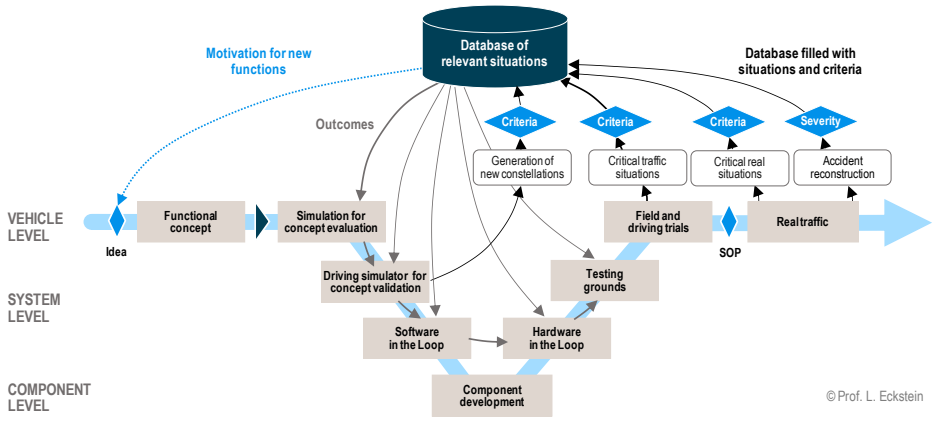
A glance at the **legal framework** indicator reveals no change in our fundamental assessment of the legal situation since the index was last published. Germany still lags a little way behind the US, due essentially to the simplified licensing procedures that exist in some US states. In this context, it is worth noting that a recent draft bill proposed for the use of automated vehicles in the state of California contains rather conservative technological stipulations and legal provisions (California DMV 2015, Draft Requirements for Public Deployment of Autonomous Vehicles). For example, a steering wheel and a driver who can take control of the vehicle at any time are still imperative at the present time. These formulations clearly reference the concepts of the likes of Google, which wants to launch vehicles with neither steering wheels nor drivers on the market in the medium term. On this side of the Atlantic, the German government has in recent weeks and months taken further steps to begin staking out a legal framework for automated driving based on the preparatory work from the round table “Automated Driving”. Key action areas have been defined in the government's "Strategy for Automated and Connected Driving" (BMVi 2015) in order to prepare Germany for both the legal and technological challenges that lie ahead. One specific need for action has been identified in relation to the ECE regulations that are binding for most European countries. ECE R79 is a case in point: At present, this regulation completely prohibits the use of automated steering functions at speeds above 10 km/h, partly because it is unclear who would be responsible. ECE R79 thus constitutes one of the critical legal obstacles to automated driving. The fact that the German government has yet to publish any concrete timeframe is part of the reason why Germany has not improved its legal framework score relative to the US.

3. Focus on testing and validation

Research into automated driving is currently being conducted in several projects. These research activities break down across five levels: the social, economical, legal, ergonomic and technical level. Technical validation and the required testing methodologies for automated vehicles in particular still constitute a challenge. Innovative approaches and the combination of testing methodologies are needed, because established approaches are enormously expensive in terms of the real mileage that has to be clocked up to test driver assistance systems. Applying these classic approaches to higher levels of automation (level 3 and above) would require millions of test kilometers to be driven, since the driver is only partially available as a fallback option, making any such systems commercially non-viable.

Germany's PEGASUS research project is looking to find an effective process and methods to validate automate vehicles, drawing on a database of relevant driving situations which is set up and operated in the long term by fka (Fig. 6). The project, in which German OEMs, suppliers and research institutes are involved, is going to be launched in January 2016 and is being funded by the Federal Ministry for Economic Affairs and Energy. Relevant driving situations are entered under controlled conditions on the basis of accident data, field trials and intensive investigations and then stored in a cooperative database. This database lays the foundation on which effective validation takes place comprising traffic scenarios in all relevant methods along the development process (V-model in Fig. 6) such as traffic simulation, driving simulators and test route scenarios.

Figure 6: Validation of automated driving functions using a database of relevant driving situations



Source: fka

4. Recent customer survey: Interest in automated driving and the use of robot taxis

In recent months, few topics have occupied the attention of the automotive industry as much as automated driving. The vehicle technologies created by OEMs, suppliers and researchers are naturally indispensable, as are appropriate legal frameworks. Yet ultimately, it is the customers – the end users – who determine which approaches succeed and which fail. Two key aspects are of paramount importance to customers:

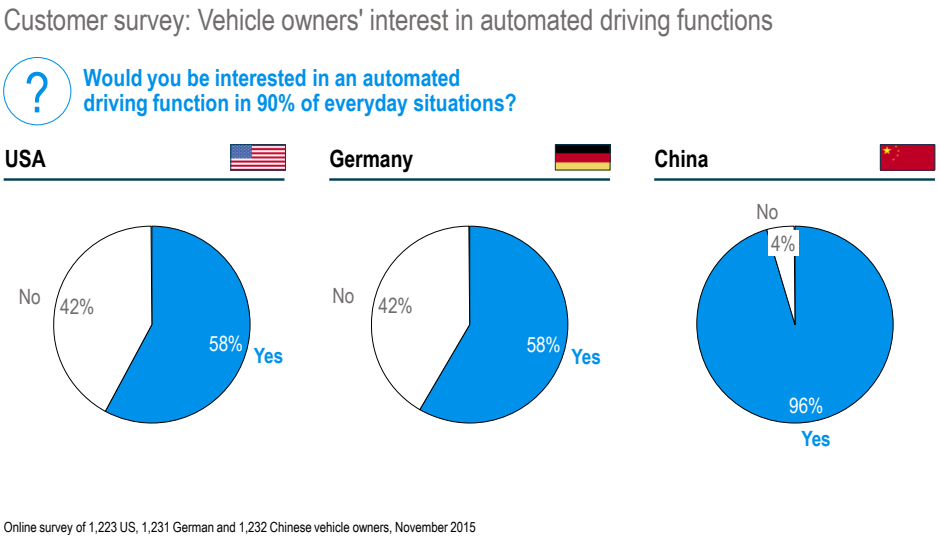
1) Safety concerns and

2) the cost of new technologies

Customer surveys vary very significantly depending on the population group they target. Regional associations and respondents' ages appear to play an especially vital role – witness the findings of a recent Roland Berger survey of vehicle owners (in the mass-market and premium segments) from Germany, the US and China. Both of the aspects listed above were investigated in the context of two key questions:

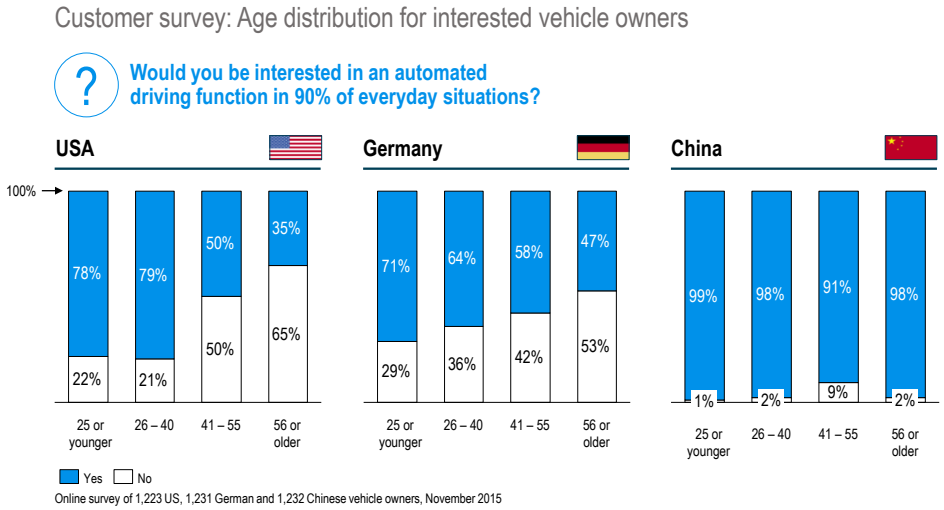
> Question 1 queried customers' fundamental interest in highly automated driving functions in everyday driving situations. While German and American customers indicated a significant positive interest (58%) despite having never experienced the technology, virtually every driver in China (96%) is interested (Fig. 7). And although Western customers become increasingly skeptical as they grow older, age appears to be of no importance in China (Fig. 8).

Figure 7: 58% of customers in Germany and the US are interested in automated driving – The figure in China is 96%



Source: Roland Berger

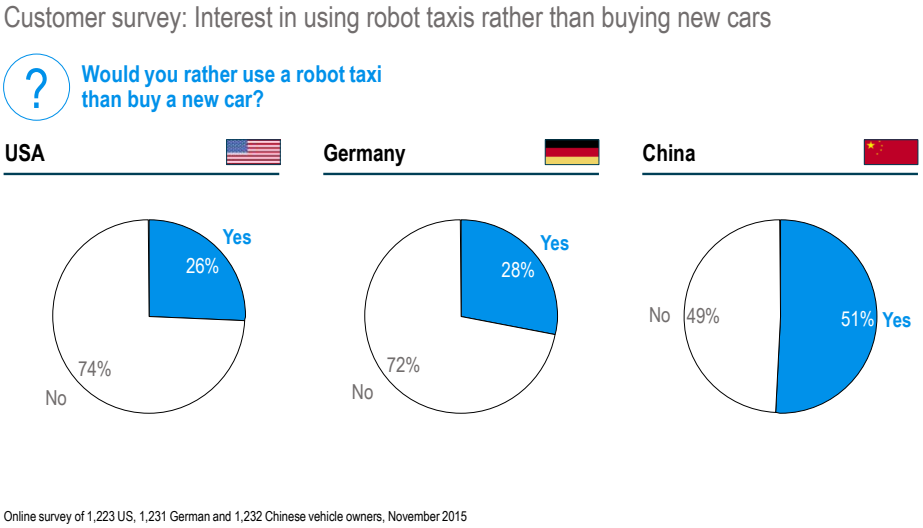
Figure 8: The older they grow, the less vehicle owners in Germany and the US are interested in automatic driving functions – In China, interest remains virtually constant even at an advanced age



Source: Roland Berger

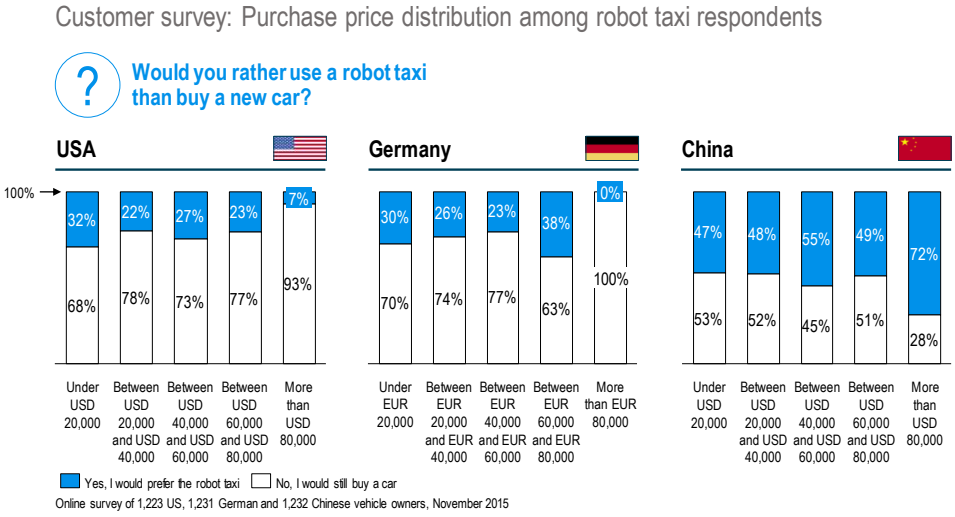
> Question 2 investigated whether car owners would rather use a driverless robot taxi than buy a new car in 2030. One basic assumption was that using this service for a given route would not be more expensive than driving a comparable distance in one's own vehicle. In this case, at least 26-28% of Americans and Germans would prefer the robot taxi option (not just the science-fiction film version!), whereas more than half of all Chinese vehicle owners – 51%, to be precise – would be interested (Fig. 9). This latter figure is undoubtedly influenced by what are already very steep licensing costs in some Chinese megacities and the widespread use of chauffeur services in China. For premium OEMs, a second aspect is particularly interesting: While virtually no Western owners of premium vehicles (priced at over EUR 80,000) would prefer to own automated vehicles (see question 1, with a share of practically 0% in favor of robot taxis), fully 72% of vehicle owners in the same segment in China would rather do without a new car and use a robot taxi instead (Fig. 10). Potentially, these figures add up to a dismal outlook for the sale of what, especially in this market, tend to be very lavishly appointed luxury cars.

Figure 9: Less than 30% of German and American vehicle owners would rather us a robot taxi than buy a new car – At 51%, interest among vehicle owners in China is greater



Source: Roland Berger

Figure 10: German and American customers in the premium segment would again opt to buy a new car – By contrast, 72% of Chinese owners in the same segment would prefer the robot taxi option



Source: Roland Berger

5. Methodology

The relative competitive position of the different automotive nations is measured on the basis of two key indicators: the industry and the market.

Industry

> OEM activities: The current state of the country's automotive industry in terms of the availability of (partially) automated driving functions in mass-produced vehicles and their realization in prototype vehicles

> Research and expertise: The country's position on knowledge and expertise in research areas of relevance to automated vehicles, as represented by the research activities of the top universities and relevant research programs

Market

> Legal framework: Comparison of the legal frameworks for operating and driving automated vehicles

> Market volume: Comparison of total sales figures with the share of vehicles sold that have relevant driver assistance functions

The individual indicators are weighted by Roland Berger and fka and compiled in the Automated Vehicles (AV) Index. Each indicator is ranked on a scale from 0 to 5. The index facilitates useful comparison of the competitive positions of the relevant automotive nations (the US, Germany, China, Sweden, the UK, South Korea, France, Italy and Japan). National automotive markets can also be compared on the basis of harmonized global benchmarks. The index thus reveals the extent to which each of the countries surveyed is able to participate in the growing market for automated vehicles. The indicators we apply are assessed based on the following parameters:

OEM activities

> The availability and performance of the (partially) automated driver assistance systems that are available in current vehicles, differentiated by vehicle segment

> The state of technological development, measured by the number and complexity of automated driving functions that the country's automotive industry currently makes available in mass-produced vehicles or has demonstrated in prototypes

Research and expertise in the field of automated vehicles

> The expertise in driver assistance systems and advanced levels of automation possessed by those of the country's universities and research institutes that are strongest on research

> The scope and breadth of research topics covered in the fields of sensors, vehicle intelligence and validation/testing, as well as adjacent fields such as connectivity and digital infrastructure in light of the depth of expertise

Legal framework

> Legal conditions governing vehicle licensing and operation, subject to due account for civil law, public law and existing norms and standards

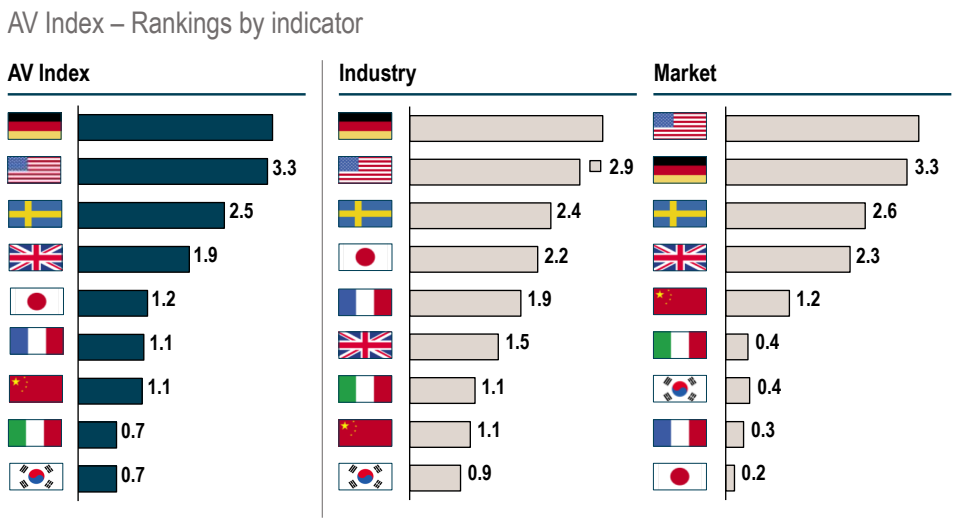
> Legal constraints with regard to liability issues and driver behavior law

Market volume

> Sales figures for all vehicles in each country, plus the share of vehicles fitted with driver assistance systems on SAE levels 2 and higher (e.g. congestion assistance systems)

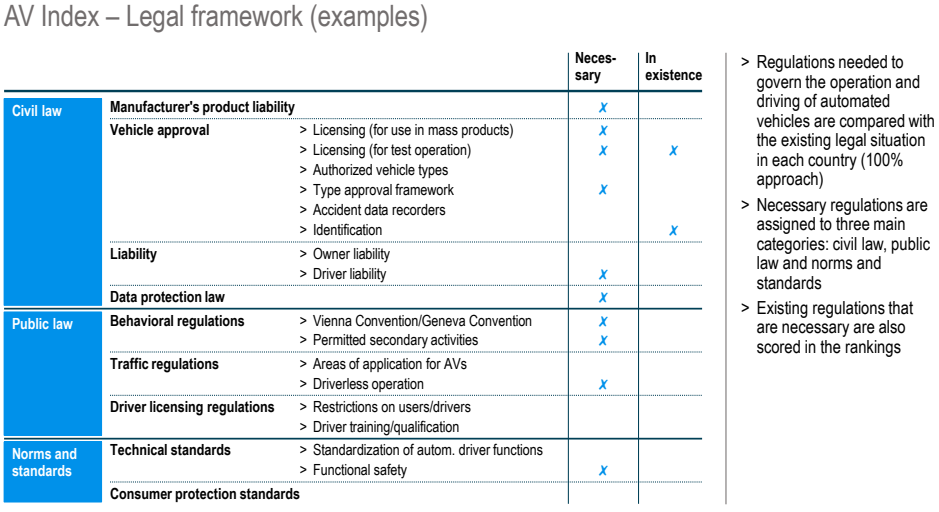
6. Appendix

Figure 11: Germany and the US lead the AV Index – Sweden lags some way behind in third place



Source: fka, Roland Berger

Figure 12: Comparison of necessary regulations with the actual legal situation – The US and Germany are pioneering legislation in this field



			Necessary	In existence
Civil law	Manufacturer's product liability		✗	
	Vehicle approval	> Licensing (for use in mass products)	✗	
		> Licensing (for test operation)	✗	✗
		> Authorized vehicle types		
		> Type approval framework	✗	
		> Accident data recorders		
		> Identification		✗
	Liability	> Owner liability		
		> Driver liability	✗	
	Data protection law		✗	
Public law	Behavioral regulations	> Vienna Convention/Geneva Convention	✗	
		> Permitted secondary activities	✗	
	Traffic regulations	> Areas of application for AVs		
		> Driverless operation	✗	
	Driver licensing regulations	> Restrictions on users/drivers		
		> Driver training/qualification		
Norms and standards	Technical standards	> Standardization of autom. driver functions		
		> Functional safety	✗	
	Consumer protection standards			

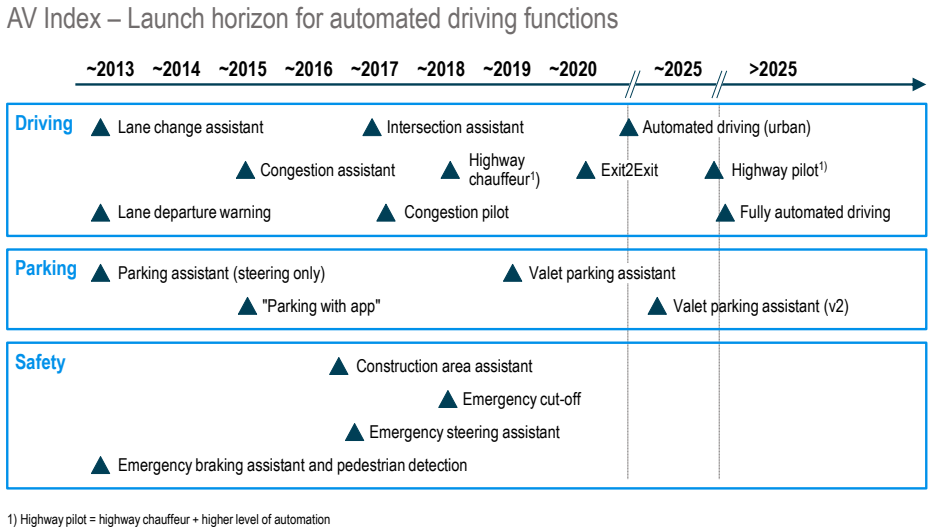
> Regulations needed to govern the operation and driving of automated vehicles are compared with the existing legal situation in each country (100% approach)

> Necessary regulations are assigned to three main categories: civil law, public law and norms and standards

> Existing regulations that are necessary are also scored in the rankings

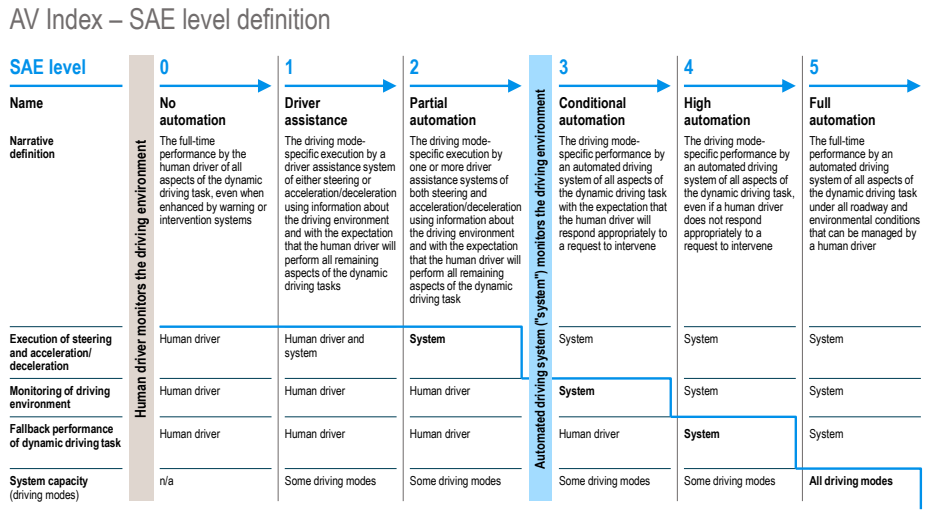
Source: fka, Roland Berger

Figure 13: OEM activities are benchmarked on the basis of all publicized driver assistance functions, including fully automated driving



Source: Press research, conference papers, fka, Roland Berger

Figure 14: Driver assistance functions of relevance to the index are those on SAE level 2 and higher



Source: SAE Int., J3016, fka, Roland Berger

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