Europäisches Patentamt
European Patent Office
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Patents and self-driving vehicles

The inventions behind automated driving | November 2018

In co-operation with eucar

Foreword

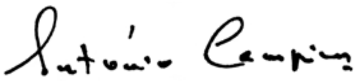
Few inventions in the 21st century stand to have as great an impact as self-driving vehicles (SDVs). Conventional modes of transport - cars, buses, trucks and other vehicles driven by humans - that we have known for the last hundred years will change entirely. A new generation of transport will arise, based on highly automated vehicles that potentially do not need human input to operate.

Many technologies that are required for SDVs have already reached consumer markets, including lane-keeping assist systems, rain-sensing wipers and automatic braking systems. If breakthroughs in technology continue at the same pace as we are currently seeing, almost all vehicle operations will be automated in the not-too-distant future. You and I will simply be the ones issuing the commands (if any are even needed, that is).

Industry and innovative enterprises are committing huge resources to the race to develop SDV technology, in the firm belief that we can all benefit from self-driving vehicles. There may be gains in fuel efficiency, reduced congestion, increased safety, more widespread public transport and innovative new transport services, not to mention potentially positive changes to our lifestyle once we are freed from the responsibility of driving.

While no one can predict the exact impact these technologies will have on our society, we can analyse current trends in patenting behaviour to help us understand how the technologies are evolving. As a leading supplier of patent information, the EPO holds a vast amount of data that can give us a unique insight into this fast-evolving sector, as companies aim to secure robust intellectual property before taking their products to market. Who are the main players in this field? How fast are these technologies evolving in comparison to other areas of technology? Which areas of SDV technology are showing the most growth? This study sets out to answer all these questions and more.

I hope that this pioneering report will prove to be a valuable source of information for policy-makers, academics, transport experts and many others who will have to anticipate and manage this period of great change in our mobility system. Because, as you read through the pages that follow, you will see that the wheels of a transport revolution are already turning - and they're turning very fast indeed.



António Campinos
President, European Patent Office

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List of countries

AT	Austria
CH	Switzerland
CN	People's Republic of China
DE	Germany
ES	Spain
FI	Finland
FR	France
GB	United Kingdom
IE	Ireland
IT	Italy
JP	Japan
KR	Republic of Korea
NL	Netherlands
OT	Others
SE	Sweden
US	United States of America

Executive summary

Aim of the study

Self-driving vehicles (SDVs) are expected to be commercially available from 2025 and have the potential to create a transport revolution. With an estimated potential market of some several hundred billion dollars per year by 2030 (A.T. Kearney, 2016), leading automotive companies are deploying massive R&D capacities to develop new technologies in this field.

A more diverse range of industrial enterprises is also becoming involved in the sector, as technology evolves in vehicles. Established automotive firms, known to be extremely innovative, must adapt to disruptive digital technologies coming from other, equally powerful industries, such as wireless communication and big data. While the new entrants traditionally have less experience in safe vehicle design, they lead in software, communication technologies and artificial intelligence (AI). Many of the underlying technologies have already been invented, and thousands of patent applications have been filed to secure the intellectual property rights to them.

This study provides a comprehensive picture of current trends and emerging leaders in SDV technologies. By looking at patent applications in this field, it gives a unique insight into the race to innovate in smart, connected and automated vehicles.

Drawing on the most recent patent information from the European Patent Office (EPO), including as yet unpublished patent applications, and incorporating advanced technology expertise in the field, it is a unique source of intelligence which will enable policy-makers and industry leaders to understand and anticipate the significant changes that are on the way.

What are self-driving vehicles?

For the purposes of this study, all technologies enabling the full automation of vehicles have been identified. The corresponding SDV patent applications have been divided into two main technology sectors, each of which is in turn subdivided into a number of SDV technology fields:

- The first sector – **Automated vehicle platform** – encompasses technologies that are embodied in the vehicle itself. It includes inventions that enable vehicles to make autonomous decisions (*Perception, analysis & decision*), inventions in the automated parts of the vehicle (*Vehicle handling*) and inventions in the underlying hardware and software technologies (*Computing*).

- The second sector – **Smart environment** – comprises technologies that enable SDVs to interact with each other and with their surroundings. It includes inventions in vehicle connectivity and related communication infrastructure (*Communication*) and inventions in traffic management, vehicle identification, automated parking and interfaces between vehicles and the electricity grid (*Smart logistics*).

Main findings

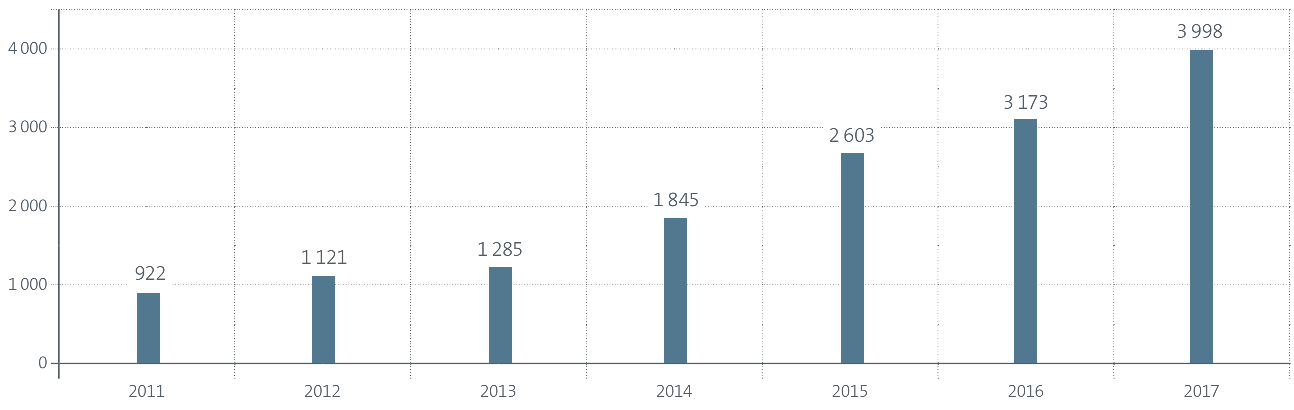
1. Steep rise in patent applications on self-driving vehicles at the EPO

Annual applications relating to SDVs increased by more than 330% compared with 2011, a growth rate that is more than 20 times faster than that for patent applications in general at the EPO in the same period.

Almost 18 000 patent applications relating to SDV technologies have been filed with the EPO in the last ten years, almost 4 000 of them in 2017 alone.

Perception, analysis & decision and *Communication* were the largest SDV technology fields in 2017. *Communication* and *Computing* were the two fastest-growing ones, with compound growth rates of 674% and 470% respectively between 2011 and 2017.

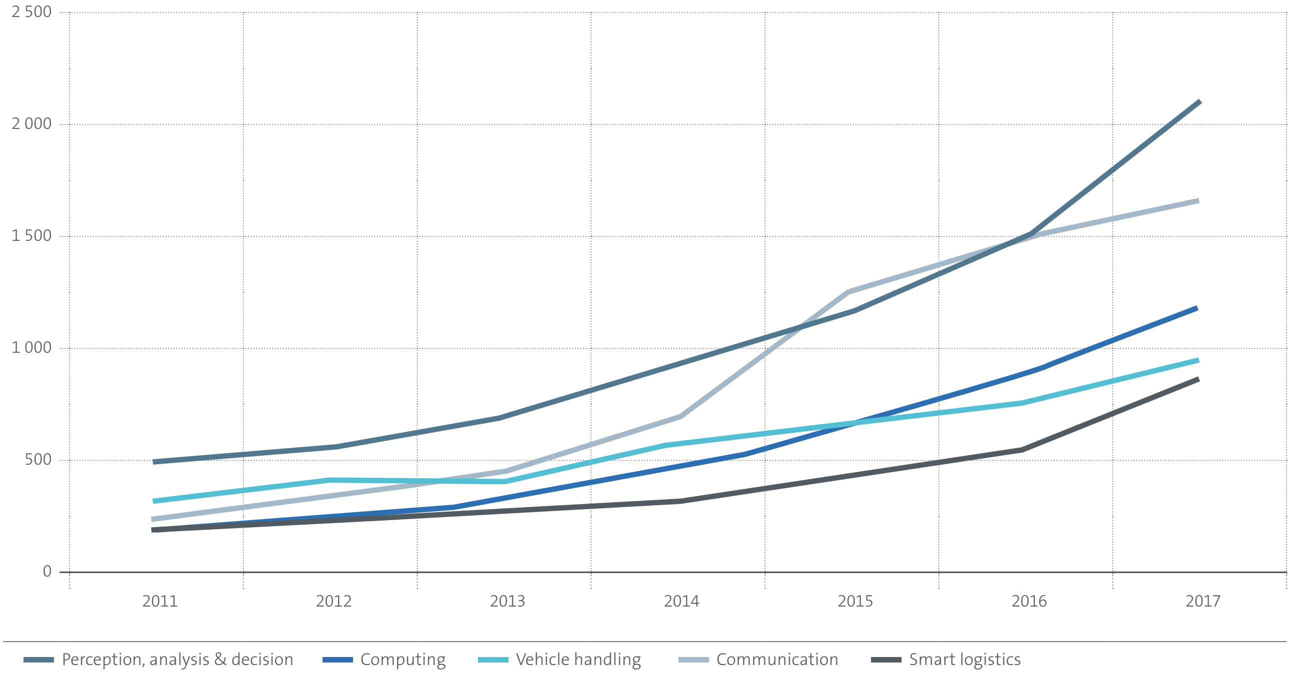
SDV patent applications at the EPO 2011-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

SDV patent applications at the EPO by technology field 2011-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

2. Patent applications in SDV involve both automotive and tech industries

SDV applications at the EPO originate from hundreds of different applicants operating in a wide variety of industries. The top 500 main applicants were responsible for 80% of all SDV applications at the EPO in the period 2011-2017. Companies operating in *Automotive*, *Other transport* or related *Machinery & electrical equipment* filed half of these SDV patent applications, while companies specialised in information and communication technologies (*ICT for automotive*) filed 32.8% and *Telecom* companies 13.6%.

Applicants in *ICT for automotive*, with 42.6% and *Telecom*, with 25.1%, clearly have their strengths in the field *Communication*. By contrast, the established *Automotive* companies have a particularly high share of patent applications in *Vehicle handling* (more than 63%), and strong positions in *Smart logistics* (48.7%), *Perception, analysis & decision* (44.4%). *Automotive* and *ICT for automotive* companies lead the *Computing* technology field with more than 30% of patent applications each.

Main applicant groups for SDV patent applications at the EPO and their technology profiles 2011-2017

	Automotive	Other transport	Machinery & electrical equipment	Telecom	ICT for automotive	Other
Perception, analysis & decision	44.4%	9.9%	13.6%	4.2%	23.8%	4.2%
Computing	33.6%	7.6%	14.4%	9.1%	30.4%	4.9%
Vehicle handling	63.4%	4.6%	15.8%	2.2%	10.8%	3.3%
Communication	18.5%	3.6%	6.9%	25.1%	42.6%	3.3%
Smart logistics	48.7%	7.0%	19.6%	5.1%	15.4%	4.1%

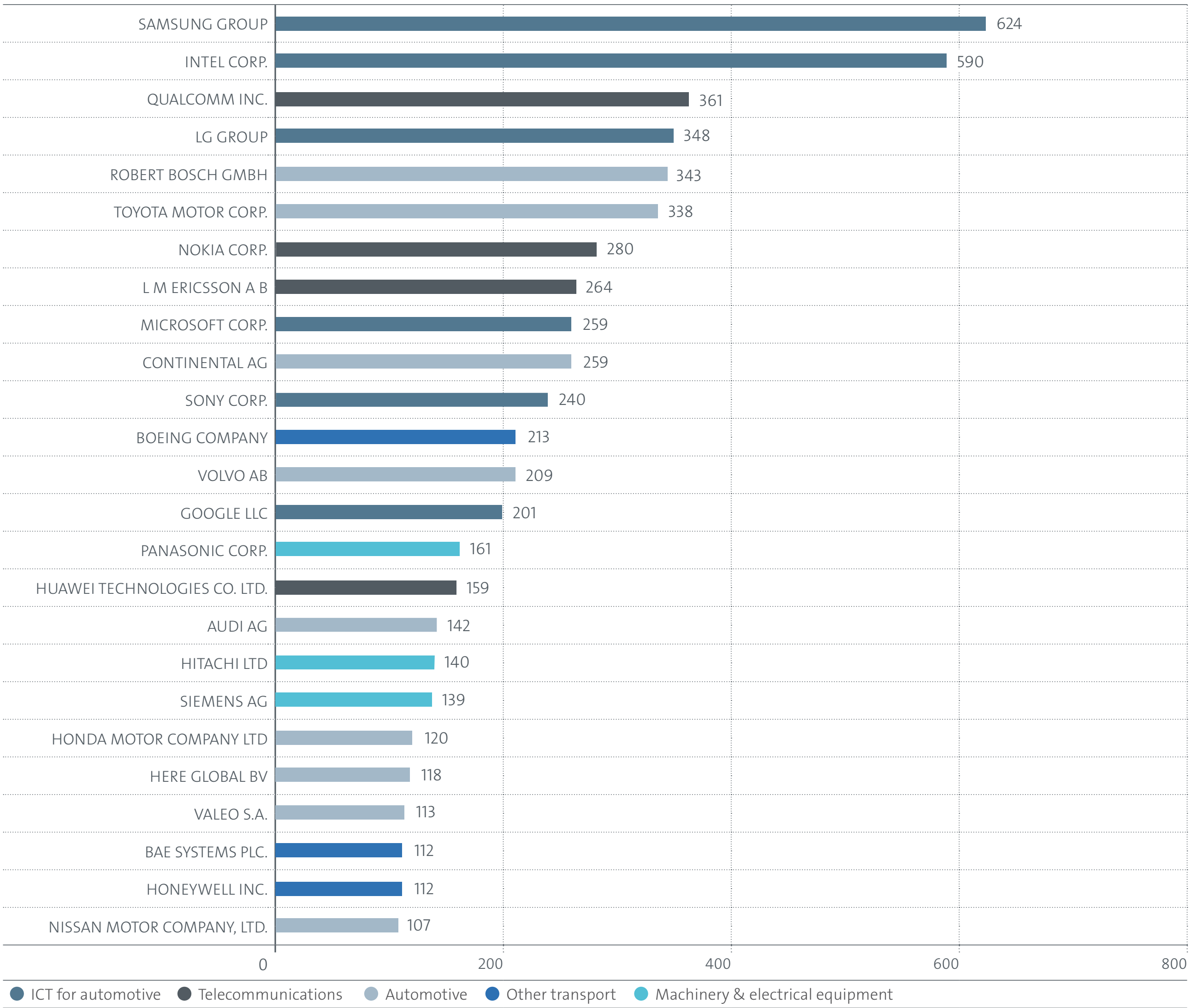
Source: EPO

The patent statistics in this table are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

The top 25 applicants accounted for a combined share of 40% of all SDV patent applications between 2011 and 2017. About half of them operate in transport or related industries, with leading positions in *Vehicle handling, Smart logistics* and *Perception, analysis & decision*.

The other half consists of applicants operating in *ICT for automotive* and *Telecommunications*. Four large tech companies top the list of SDV applicants, due to high shares in patent applications in the *Communication* and *Computing* technology fields.

Top 25 SDV applicants at the EPO 2011-2017



Source: EPO

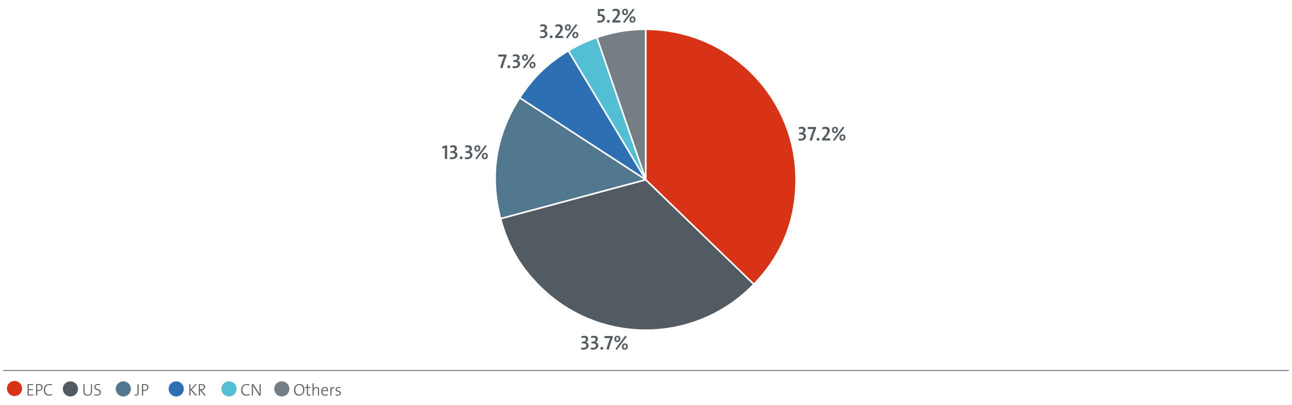
The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

3. Europe and the USA lead the way in SDV innovation

Europe (EPC) and the USA have a strong lead in SDV innovation, with about 1 400 patent applications each in 2017 alone. In the same year, Japan accounted for 468 applications, the Republic of Korea for 382 and the People's Republic of China for 194.

US applicants dominate in *Communication* and *Computing* technologies, while European applicants stand out in *Vehicle handling, Smart logistics* and *Perception, analysis & decision*.

Geographic origins of SDV applications at the EPO 2011-2017



Source: EPO

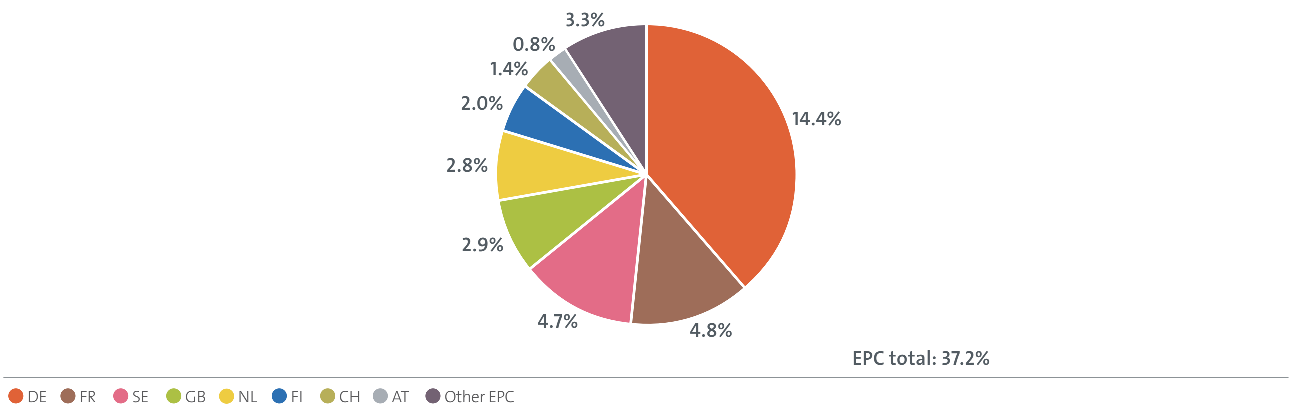
The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

4. In Europe, Germany is the established leader

Germany is the most active country in Europe, with 2 151 applications between 2011 and 2017 (more than 500 of them in 2017 alone).

Over the same seven-year period, Sweden and France had about 700 applications each, followed by the United Kingdom and the Netherlands with about 400 applications each.

European origins of SDV applications at the EPO 2011-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

5. Patent applications in SDV technologies aim at broad international protection

Patent filing strategies for SDV inventions are also different from those observed in established automotive technologies. The average size of patent families, indicating the number of countries in which patent protection was sought for one invention, is significantly bigger in SDV fields.

Patent protection on SDV inventions is also more frequently sought with regional (EPO) or international patent offices (PCT route), suggesting that broad international protection is critical in the SDV market.

Patent families in established automotive technologies versus SDV technologies in Europe 2011-2015

	Self-driving vehicles	Established automotive
Average patent family size	4.8	3.2
Share of patent families with regional (EPO) or international (PCT) applications	76.7%	51.3%

Source: EPO

The patent statistics in this table are based on all inventions, i.e. patent families, in established automotive technologies or SDV technologies for which a patent application has been filed in one of the official languages of the EPO, and with at least one patent application filed with the EPO or a patent office of a contracting state to the EPC. The reference date for each patent family is the date of the earliest patent filing at the EPO or one of the national offices of the EPC contracting states.

Introduction

Self-driving vehicles (SDVs) are no longer just a distant dream. Set to revolutionise society by offering fully automated transport, they are one of the most striking examples of the new smart connected objects resulting from the Fourth Industrial Revolution (EPO, 2017). Advanced driver assistance systems, including adaptive cruise control, hill-start assist, park assist and lane-keeping assist, are already on the market. Automotive manufacturers, their suppliers and other tech companies are all currently engaged in pilot tests, running self-driving cars for thousands of kilometres on public roads. Automated freight transport and logistics are also set to come into use, following the successful conclusion of cross-border truck platooning projects.

Towards full automation

Such achievements herald a deep and imminent transformation of the whole transport system, with far-reaching implications not only for passengers moving from A to B, but for all stakeholders in the automotive industry and beyond. SDVs can potentially improve road safety, increase energy efficiency and reduce road congestion. Those previously excluded from private transport, such as the elderly, blind or disabled, could gain new mobility. Effects on jobs and growth are expected, with an increased need for digital skills in the automotive sector. Professional drivers will still be needed in the transition phase of mixed automated and non-automated transport, but their job profile is likely to change significantly.

A growing market

In addition to the impact of such changes on our society, the market potential is also enormous. Estimates show that the value of the market in SDVs could be in the region of several hundred billion dollars by 2030 (A.T. Kearney, 2016).

Accordingly, the amount of investment is also high. More than 80 billion US dollars was invested in the development of SDVs between 2014 and 2017 alone, and this amount is expected to continue to grow in the years ahead (The Brookings Institution, 2017).

There are also more companies entering into this market. For the first time, giant automotive companies producing millions of vehicles every year have to adapt disruptive innovations stemming from other powerful companies in information and communications technology (ICT). SDVs will also disrupt many established industries and give rise to new ones. The race is on with new entrants that have no track record in vehicle design, but a lead in software, sensors, AI and communication. Automotive companies have entered into it with massive research and innovation (R&I) capacities and a long experience of established vehicle technologies.

Fuelling innovation and patent applications

Although fully self-driving vehicles are not expected to be commercially available until 2025 (A.T. Kearney, 2016), many of the underlying technologies have already been invented, and thousands of patent applications have been filed to secure the intellectual property rights to them. For patent offices, this development has resulted in the rapid growth of a new breed of inventions, mixing features from ICT and established automotive technologies.

These patent applications define the technologies used in SDVs. Vehicles will be able to detect and analyse fixed and moving obstacles and to communicate with each other. Satellites and stationary and mobile broadband networks will provide information about road maps and traffic and weather conditions. Powerful onboard computers and artificial intelligence will enable them to rapidly process these vast amounts of data for appropriate controlling of the vehicle, taking into account the comfort and safety of passengers and other road users.

Focus of the study

The aim of this study is to provide a comprehensive and up-to-date picture of the current trends and emerging leaders in SDV technologies by analysing patent information. The study draws on the EPO's most recent patent data (including as yet unpublished patent applications) and advanced technology expertise in the field to identify SDV inventions. As such, it provides a unique source of intelligence which will enable policy-makers and industry leaders to understand and anticipate the significant changes that are on the way.

The primary focus of the study is patenting activity for SDVs in Europe, which in 2017 represented 18% of global motor vehicle sales and 20% of the world's production (ACEA, 2018). For this reason the core analysis is based on inventions filed with the EPO.[1] This selection allows for the creation of comparable, up-to-date patent statistics that report on trends in SDV inventions in Europe in the years leading up to 2017.

The report provides a comprehensive overview of the technologies that are necessary to enable the deployment of self-driving vehicles. The relevant patent applications have been identified and assigned to one or more subsectors of SDV technologies depending on the technical aspects of the invention. The resulting patent statistics indicate technological and market trends relating to self-driving vehicles and the services around them. Other metrics have been deployed to assess the performance and technology profiles of countries and companies, helping to uncover new industry dynamics.

Outline of the study

Chapter 1 provides insight into the current innovation trends towards self-driving vehicles. Chapter 2 introduces the cartography of technologies that is used to identify and categorise inventions relating to SDVs. Building on that cartography, Chapter 3 compares patent applications for SDVs with those in established vehicle technologies. Chapter 4 analyses trends in patent applications on SDV at the EPO and developments in the different subsectors of SDV technologies. Chapter 5 looks closely at the applicants of SDV inventions at the EPO and their respective technology strengths. Chapter 6 reports on the global and European origins of SDV patent applications. Chapter 7 provides a summary of the findings.

Patents support innovation, competition and knowledge transfer

Patents are exclusive rights that can only be granted for inventions that are novel, involve an inventive step and are industrially applicable. High-quality patents are assets that can help attract investment, secure licensing deals and provide market exclusivity. Applicants pay annual fees to maintain patents that are of commercial value to them; the rest lapse, leaving the technical information disclosed in them free for everyone to exploit. A patent can be maintained for a maximum of twenty years. In exchange for these exclusive rights, all patent applications are published, revealing the technical details of the inventions in them. Patent databases, therefore, contain a wealth of technical information, much of which cannot be found in any other source, which anyone can use for their own research purposes. The EPO's free Espacenet database contains more than 100 million documents from over 100 countries and comes with a machine translation tool in 32 languages.

1 In chapters 2 and 3, the scope of analysis is extended to include inventions for which an application has been filed with one or more of the national offices of the EPC contracting states, regardless of whether it has also been filed with the EPO.

1. The road to vehicle automation

1. The road to vehicle automation

This chapter provides a perspective on the main challenges for industry raised by the development of self-driving vehicles. It reviews general innovation trends in the automotive industry before presenting in more detail the current frontier of research and innovation towards full vehicle automation.

1.1 Innovation trends in the automotive industry

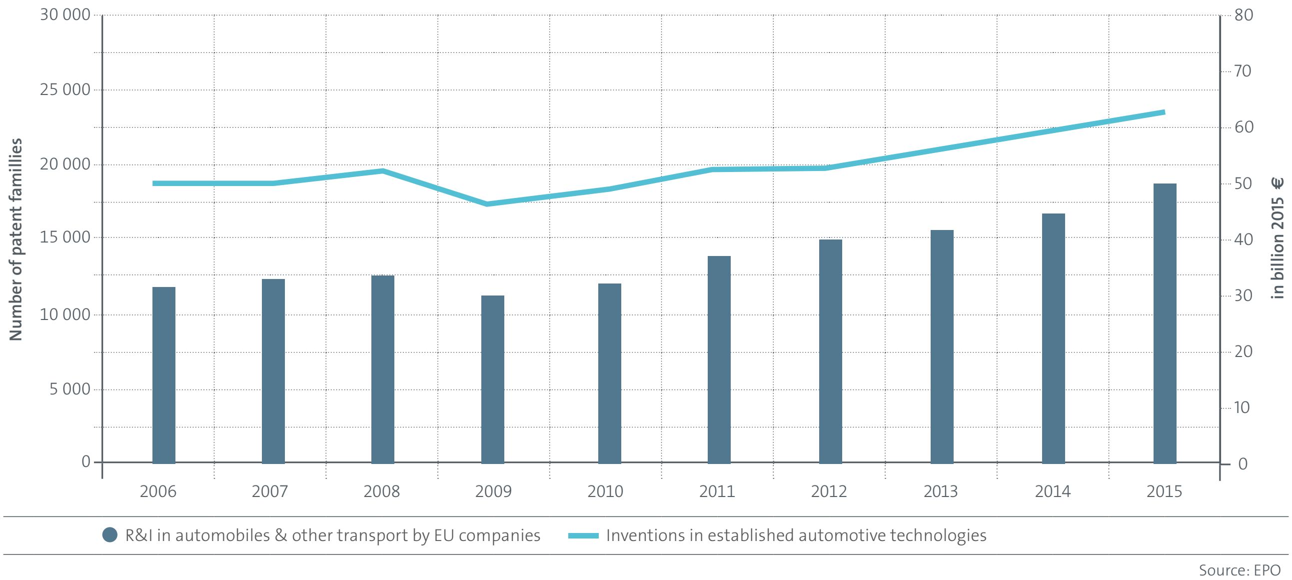
The automotive industry is a major economic actor and an innovation leader in Europe. It provides more than 13 million direct and indirect jobs in the European Union, representing 6.1% of total employment in 2016 and generating a net trade surplus of €90.3 billion in 2017 (ACEA, 2018). It is the biggest private investor in research and innovation (R&I) in the EU, spending more than €54 billion in 2016 alone. These R&I investments enable the industry to remain a global technology leader.

The automotive sector is also a patent-intensive industry.[2] The growth in automotive R&I investment is reflected in its contribution to patent applications in Europe (Figure 1.1). Between 2006 and 2015, patent applications were filed for over 200 000 inventions relating to established automotive technologies with patent offices in Europe.[3] This upward trend remained almost unbroken throughout the whole period, despite a sharp but temporary decline following the financial crisis of 2007/2008. Between 2009 and 2015 alone, the number of inventions for which patent protection was sought in Europe increased by 36.2% to 23 829.

However, the European, but also global, automotive industry may be on the verge of a fundamental transformation, triggered by the need to address important societal challenges. The automotive industry will have to continue providing cleaner, safer, more efficient, more sustainable and more inclusive transport solutions. At the same time, companies will need to remain competitive in order to continue creating jobs and economic growth for Europe.

Figure 1.1

Inventions patented in Europe in established automotive technologies and R&I expenditure by the European automotive industry



Source: EPO

The patent statistics in this figure are based on all inventions, i.e. patent families, in established automotive technologies for which a patent application has been filed in one of the official languages of the EPO, and with at least one patent application at the EPO or a patent office of a contracting state to the EPC. The reference date for each patent family is the date of the earliest patent filing at the EPO or one of the national offices of the EPC contracting states. R&I expenditure by the European automotive industry is derived from the EU Industrial R&D Investment Scoreboard provided by the European Commission.

2 See for example EUIPO-EPO (2016) report on "Intellectual property rights intensive industries and economic performance in the European Union".

3 Established automotive technologies comprise all the technologies that can be found in today's mass-produced vehicles which do not include the features of connectivity and automated driving. In particular, they include the following technical fields and associated CPC classes: signalling and lighting (B60Q), braking systems (B60T), clutch controls (F16D48), steering & chassis (B62D), suspensions (B60G), peripherals e.g. airbags (B60R), engine exhaust (F01N), turbochargers, air intake manifolds, pistons etc. (F02B), control of engines (F02D), pistons (F02F), carburettors, fuel injection (F02M), starting of combustion engines (F02N), ignition (F02P), sparking plugs (H01T), wheels (B60B), tyres (B60C), vehicle connections (B60D), heating, cooling etc. of vehicle cabins (B60H), windows, windscreens (B60J), seats (B60N), conjoint control (B60W), transmission in vehicles (B60K).

Two major trends are driving the transformation. The first, the *decarbonisation* of road transport, aims at reducing carbon intensity and emissions per unit by innovating in sustainable propulsion technologies (e.g. advanced internal combustion engines and hybrid electric, plug-in hybrid electric, battery electric and fuel-cell hybrid electric vehicles). It represents a major part of innovation in established automotive technologies, with protection being sought for 9 577 inventions in Europe in 2017 alone. The second major trend is the increasing level of automation towards fully self-driving vehicles. It is primarily driven by digitalisation and is the focus of this study.

1.2 Challenges and opportunities

Connected vehicles are progressively entering the market and are expected to shape the transport sector in the second and third decades of this century. Future mobility solutions and vehicles are set to take advantage of ever-growing computing power, high-speed connectivity, deep learning algorithms for artificial intelligence and fast and decentralised data handling. Through the rapid technological evolution in the telecom, IT and semiconductor industries, a completely new range of applications for smart and safe mobility appears increasingly possible.

These developments will have a major impact on our transport system, including road use and traffic management. Connected automation could significantly increase safety and efficiency. Congestion, especially in urban areas, may decrease. When evaluated together, all these changes stand to potentially increase the quality of our lives. However, there are still a number of challenges to be addressed:

Cyber security – Cyber security needs to be ensured. Increased connectivity requires secure data transfers and protection of a vehicle's internal communication against outside intrusion (i.e. hacking). At the same time, hackers have increased access to greater computing power.

Verification and validation – Automated driving and automated vehicle functions also need verification and validation of safe operation. To account for the multitude of different driving situations that will be encountered by SDV, numerous scenarios need to be tested and automated responses validated. Virtual testing and certification might be the way forward. For higher levels of automated driving, where the driver is not *always* in the loop, a drastic increase in testing and validation is foreseen, given the comprehensive range of traffic scenarios to be considered.

Co-existence with other road users – The transition period in which vehicles and their users move from low to high levels of automation poses significant technical and operational challenges in itself. For example, how can automated, semi-automated and non-automated vehicles and their users co-exist safely? And, how can driver behaviour in automated road transport be better understood to avoid risks and confusion?

Managing interaction with SDVs – In order to achieve wider acceptance and a mass market for automated vehicles, automated manoeuvres need to be readable and understood by humans at any time and in any traffic context, irrespective of adverse environmental conditions or different human characteristics. Research is necessary to evaluate the effects of the functions and whether drivers' intentions and actions have to be included in the design of the automated functions to achieve the overall system performance.

For higher levels of automation, the role of the driver and their interaction with the vehicle will change. Drivers must have a very clear understanding of the actual level of automation in each traffic situation. The monitoring of driver readiness for handover and driver/vehicle co-operation are also important factors when it comes to ensuring safe driving behaviour.

Managing vehicle design – With higher levels of automation and an increasing amount of information, alerts and content available, the vehicles of the future will look different. This means that vehicles driven by humans, whether all or part of the time, must always guarantee a "safety margin" to the vehicle occupants and other road users. This poses a major challenge when it comes to designing new interaction modalities between humans and vehicles.

Future integrated mobility: vehicles, business models and solutions – A prosperous eco-system enabling new and innovative ideas for services, vehicles and applications across the value chain is starting to unfold. There are already new emerging business models for shared vehicles, such as car-sharing, ride-sharing and car-pooling. In combination with cloud computing and cloud services, SDVs could provide new opportunities for innovative business models from both established businesses and start-ups (see case study on robot taxis).

Comfort and convenience – Vehicle automation could create value for drivers, businesses and customers by providing enhanced comfort and convenience and means of increasing productivity.

Personalised transport solutions – With higher levels of automation being deployed, it will be possible to develop more personalised mobility services. *Mobility as a Service* (MaaS) is seen as a logical step towards closing the gap between public and private means of transport. This new situation/trend might change the requirements and user expectations for future vehicles entirely. However, its impact on society will be influenced by customer acceptance of self-driving vehicles.

Environmental sustainability – For freight transport, the implementation of a more connected transport system with connected automated vehicles, goods and infrastructure has great potential to improve not only utilisation rates and freight efficiency but also the safety and environmental sustainability of transport (see case study on truck platooning).

Case study 1: Robot taxis

What are robot taxis?

Robot taxis – also called cyber vehicles – are self-driving taxis or shuttles. By their ability to bring passengers to any destination at any time, they have enormous potential to shape and influence future means of transport and mobility. Robot taxis will be initially developed as Level 4 automated vehicles, restricted to low driving speeds and city journeys. In their final stage of development, they will be required to autonomously manage all road and environmental conditions, including rural roads in remote areas, busy motorways, residential areas and central business districts.

Robot taxis will be capable of door-to-door service, as well as automatic parking where required. Such services will contribute to greater mobility for all, allowing people to access transport services regardless of their age or physical condition. They are also expected to reduce the need for conventional parking spaces, promote shared mobility and decrease congestion, energy consumption and vehicle emissions.

What technology is involved?

In order to be able to pick up users and deliver them to any desired destination, robot taxis will require the highest level of automation. This relies on a comprehensive set of in-vehicle technologies combined with cloud-based and infrastructure-related technologies. New business models are being developed, using novel data management systems that are fully integrated with digital and physical infrastructures.

Sensing and sensor fusion, which is the combination of data from different sensors, are fundamental. Fully autonomous vehicles will require a combination of different sensors, such as cameras, radar and light detection and ranging (Lidar), as well as the ability to fuse the information (sensor fusion). Data from different sensors are needed for gaining "360° awareness", in order to ensure the highest safety and reliability (fault operational requirements) levels.

By fully perceiving the environment (360° awareness and world model), automated vehicle systems will be able to predict the next few seconds and take a decision on how to react. Real-time data processing is therefore crucial for handling the huge amount of data obtained by the vehicle from the surrounding environment, traffic and other information sources. AI techniques such as machine learning (including deep learning) will therefore be crucial for decision-making in automated vehicles. They will allow the vehicle to understand future scenarios and drive safely and efficiently.

These in-vehicle enablers (sensors, sensor fusion, hardware and software components) will be complemented by the digital infrastructure needed to manage communication between vehicles and the infrastructure and to provide new mobility services. Communication will enable the use of external data sources, combining high-definition maps of dynamic and static information from "outside" the vehicle. This could include information on roads, lanes, map data, speed limits, work zones, other vehicles, pedestrians and weather information. In addition, connectivity could be used to facilitate robot taxis services through communication with the fleet management system and provide information on customer pick-up location, service requests, (cyber)security, maintenance, refuelling, billing and other services.

Future trends

As with any new technology, it will be necessary to ensure a smooth co-existence between automated and non-automated "conventional" vehicles during the transition period. It is anticipated that mixed traffic and associated services will gradually evolve into a higher degree of automation, with robot taxis playing an important role by providing inclusive new mobility services. It is possible that existing business models in automotive and transport might also change, affecting not only vehicle manufacturers, but also taxi providers, rental cars, and car-sharing and fleet management companies. For some users, the potential for reduced costs per mile will be a convincing argument for choosing shared mobility services instead of conventional taxis or owning a vehicle.

Societal acceptance is another factor affecting the success of driverless vehicles, as road users may have questions about interaction between SDVs and other road users, safety and trust in new technologies. A socio-economic impact assessment of robot taxis on jobs, education and services will also be needed in order to manage expectations and define the best implementation route.

Case study 2: Truck platooning

What is truck platooning?

Truck platooning is the linking of two or more, trucks in a convoy in which vehicles closely follow each other at a set distance using connectivity technology and automated driving support systems. The truck at the head of the platoon acts as the leader, with the vehicles behind reacting and adapting to changes in its movement.

The trucks automatically maintain a short distance between each other when they are connected for certain parts of a journey, such as on motorways. Parts of the route are still conventionally driven and drivers are responsible for system controls at all times, so they can decide to leave the platoon and drive independently.

Platooning has great potential to make road transport safer, cleaner and more efficient. It results in lower fuel consumption, as the trucks drive closer together at a constant speed, with less braking and accelerating. It also has the potential to reduce carbon dioxide emissions. Likewise, connected driving can help improve safety, as braking is automatic, with virtually zero reaction time compared with human braking. Finally, platooning also optimises transport by using roads more effectively, reducing traffic jams and delivering goods faster.

Technology description

In platooning, the truck at the head of the platoon acts as the leader, with the vehicles behind reacting and adapting to changes in its movement. The platoon leader is in charge of defining the speed and manoeuvres, while the rest of the vehicles in the platoon follow its movement. For example, if the platoon leader brakes, all the other trucks in the platoon also brake.

The technologies involved in platooning include communication systems to allow vehicle-to-vehicle (V2V) communication; communication protocols to ensure a reliable and safe transfer of data; advanced driver assistance systems (ADAS) including steering functions, braking functions and advanced emergency braking systems (AEBS) to perform the manoeuvres necessary to form, operate and dissolve the platoon; and finally driver monitoring and human-machine interfaces to ensure driver awareness.

Vehicle-to-vehicle (V2V) communication systems use the radio/antenna and the vehicle's computer to share location and movement information with other vehicles. That information is then analysed and used to alert the driver to potentially hazardous situations. More advanced systems may also employ vehicle-to-infrastructure (V2I) communications that allow vehicles to receive driving condition information from traffic lights, road signs or even the road itself, including notifications relating to traffic congestion, speed limits and height restrictions on bridges and tunnels.

ADAS includes vehicle-based intelligent safety systems designed to assist drivers. Some of these systems directly improve road safety in terms of crash avoidance, crash severity mitigation and protection, while others are designed for the driver's comfort. When V2V and V2I communication capabilities are integrated with ADAS, a vehicle could take control of the brakes and/or steering to avoid a collision if the driver fails to react in time. In a platooning rear truck, longitudinal control and braking are automatic. The V2V link allows the lead truck to control the acceleration and braking of both trucks virtually simultaneously, reacting nearly instantaneously. Trucks can safely follow at minimal distances and save fuel, improving road safety and traffic flow.

What's next?

Truck manufacturers and logistics operators are eager to bring platooning to Europe's roads, and the first real-life tests are underway. The technology for platooning with trucks of the same brand ("mono-brand platooning") is already available. However, there is a need for standardisation to enable different proprietary (multi-brand) platooning technologies to interact. When forming a scalable, multi-brand truck convoy, the vehicles must be compatible to ensure correct and safe operation across borders. Different solutions are being explored to ensure robustness, reliability and interoperability across different brands and countries. The technologies involved will be mainly based on communication hardware and software and cloud-based services, complemented by automated safety and security mechanisms.

For platooning to be implemented, it will therefore also require the development of policies and a regulatory framework based on testing and validation processes. Data and knowledge gathered from pilot tests across Europe will provide a sound scientific basis for defining comprehensive validation procedures for multi-brand platooning before its final implementation on the roads.

A number of new services relating to truck platooning will be available in the near future. Traffic flow information will facilitate real-time monitoring of truck platoons driving on roads and platoon routing, providing rules on where to enable and disable the platooning systems.

By 2023, it should be possible for multi-brand platoons to drive across Europe on motorways, crossing national borders and allowing the driver of a trailing truck to rest while driving. Fully autonomous trucks are expected to follow.

2. Mapping SDV inventions to patent data

2. Mapping SDV inventions to patent data

This chapter explains how the concept of self-driving vehicles has been mapped, for the purposes of this study, to the different categories of patent applications that constitute its technological building blocks. The resulting cartography provides the basis for the patent landscape of SDV inventions presented in the chapters that follow.

2.1 A cartography of SDV inventions

A vehicle can function at different levels of automation, depending on the sophistication and capabilities of the technologies used (see chapter 1). The Society of Automotive Engineers (SAE) International defines six different levels of automation in vehicles, ranging from level 0 (practically no driving automation) to level 5 (full automation).[4]

This study is based on all the inventions that will enable the realisation of a vehicle with self-driving capability as described by levels 4 (high automation) and 5 of the SAE international standard. It is based on a rigorous identification and selection of all related patent applications, and covers general technologies, such as 5G networks and cloud computing, as well as application-specific automotive technologies, e.g. vehicle electrification and powertrains, as far as they are relevant for vehicle automation.

These SDV inventions are divided into two main sectors, each of which is in turn subdivided into a number of technology fields (see Table 2.1 for an overview with examples).

- The first sector – **Automated vehicle platform** – encompasses technologies that are embodied in the vehicle itself. It comprises three fields: *Perception, analysis & decision*, *Vehicle handling* and the underlying *Computing* technologies.

- The second sector – **Smart environment** – comprises technologies that enable automated vehicles to interact with each other and with their surroundings. It consists of two fields: *Communication* technologies and *Smart logistics*.

The detailed scheme, where the five technology fields that form the second layer of aggregation are further subdivided into twelve basic building blocks and additional examples, is described in Annex 7.2.

4 This typology is based on standard SAE J3016 of the Society of Automotive Engineers (SAE) International. The detail of the typology is reported in Annex A.1

2.2 Patent data

The patent analysis presented in chapters 5 and 6 is based entirely on patent applications filed with the EPO (applications filed direct with the EPO or international (PCT) applications that entered into the European phase) in the period 1990-2017. Patent applications for protection filed exclusively at national patent offices have not been included, so the statistics do not fully reflect applicants' overall innovation capacity. In particular, some vehicle manufacturers often file with patent offices of contracting states to the European Patent Convention (EPC) only and their inventions may therefore be underrepresented when considering patent applications at the EPO. However, a strict focus on patent applications at the EPO also has several important advantages.

First, it makes it possible to report on the most recent patent statistics for the European market, including unpublished patent documents filed in 2017 and only available in the EPO's internal databases.

Second, it creates a homogeneous population of patent applications which can be directly compared with one another, as these applications have been filed with the same patent office, seek protection in the same geographical market (Europe) and have all been classified by EPO patent examiners. This approach avoids the national biases that usually arise when comparing patent applications across different national patent offices.

A third advantage of focusing on EPO patent applications is that, in most cases, one patent application can be considered as representing one technical invention.

However, care needs to be taken when comparing patent applications originating from within Europe with those from outside. While European applicants are targeting their home market when they file a patent application with the EPO, non-European applicants are targeting a foreign market. Nevertheless, comparisons are still justified and informative, since even European patent applicants only use the EPO if they are targeting a market that goes beyond their national one. Otherwise they would most probably file a patent application with their national patent office only.

In line with the EPO's official reporting method for annual statistics, the reference year used for all statistics is either the filing year of the European patent application (for applications filed direct with the EPO (Article 75 EPC)) or the year of entry into the European phase (for international (PCT) patent applications (Article 158(2) and Rule 107 EPC)). Each EP application identified as relevant for building block technologies is assigned to one or more sectors (layer 1), fields (layer 2) or building blocks (layer 3) of the cartography depending on the technical features of the invention.

In order to enable further analysis of the filing strategies of applicants in SDV technologies, the scope of analysis was extended in chapter 4 to include national patent applications in contracting states to the European Patent Convention (EPC). All patent families[5] filed in one of the official languages of the European Patent Office (EPO), and with at least one patent application filed with the EPO or the patent office of a contracting state to the EPC, were considered. The date assigned to each patent family is then the filing date of the earliest patent filing in Europe, and statistics are reported up to and including 2015.

Where necessary, the dataset was further enriched with bibliographic patent data from PATSTAT, the EPO's worldwide patent statistical database, as well as from internal databases, providing additional information, for example, about the names and addresses of applicants[6] and inventors. Applicant names have been harmonised to enable the analysis of top applicants presented in chapter 6. The harmonisation process was carried out for patent applications filed with the EPO in the period 2011-2017 and was based on the method used for the EPO's annual report and statistics. When creating statistics based on origin of applicant, only the country of the first applicant was considered.

5 A patent family is a set of interrelated patent applications filed in one or more countries to protect the same or a similar invention by a common inventor and linked by a common priority or priorities. This study uses the DOCDB simple patent family concept, under which all members of a patent family have exactly the same priorities.

6 Applications are assigned according to the country of the first applicant only. An analysis based on the country of inventors using fractional counting delivered similar results.

Table 2.1

Cartography of SDV inventions

Sectors	Technology fields	Examples of technologies included
Automated vehicle platform	**Perception, analysis & decision**	– Short-, medium-, long-range radar for adaptive cruise control – Cameras for lane departure warning/control, traffic sign recognition, surround view – Navigation and mapping systems – Adaptive cruise control (ACC) and platooning – Scene perception and modelling – Vehicle stability, dynamic chassis control, conjoint control of stability systems
	Computing	– Bus systems – Supervisory systems for fault recognition and recovery – Artificial intelligence – Computer security – Diagnostics and fault management
	Vehicle handling	– Automatic steering – Vehicle suspension control – Control systems for road vehicle drive control – Powertrains: battery electric vehicles (BEV); hybrid vehicles; efficient internal combustion engine vehicles
Smart environment	**Communication**	– 5G network – MM wave antenna arrays technology – Cloud for learning and updating high-definition maps and traffic data – Cellular communication systems for vehicle applications – Traffic signal arrangements – Road embedded sensors and signalling – Connection management for emergency connections (eCall)
	Smart logistics	– Fleet management – Traffic control systems for road vehicles – Automated parking – Inductive on-road recharging systems – Smart grids in transport

3. Characteristics of SDV inventions

3. Characteristics of SDV inventions

This chapter aims to position automated vehicle technologies within the broader technology landscape of the automotive industry. SDV technologies are compared with a benchmark population of patent applications relating to established automotive technologies. For this purpose, all inventions for which one or more patent applications has been filed in Europe in one of the EPO official languages are considered, up to and including 2015.

3.1 A new breed of automotive technologies

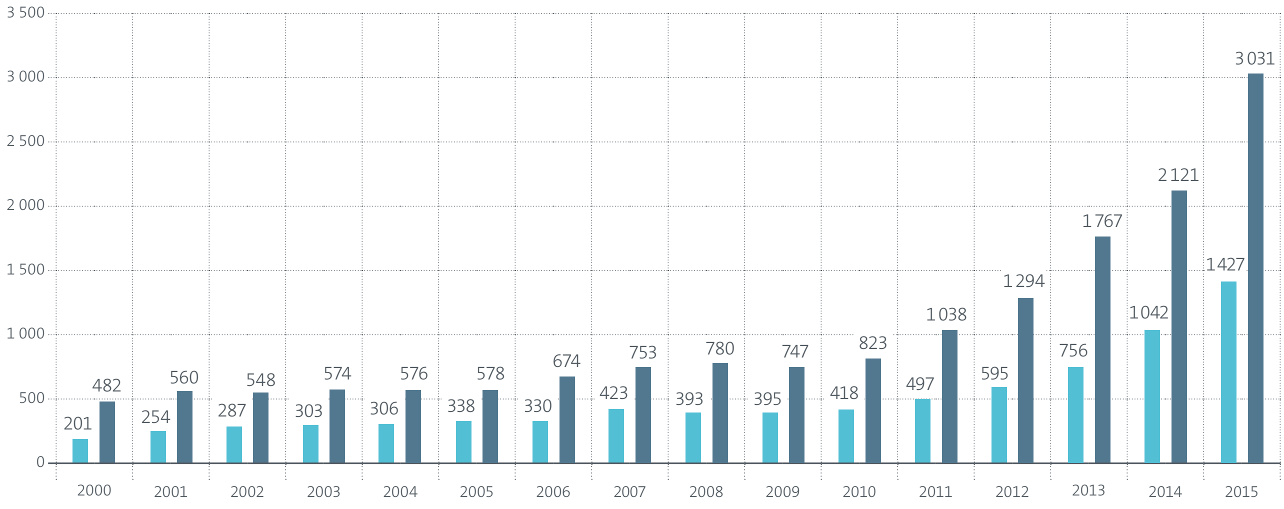
Between 2000 and 2015, a total of 24 311 inventions relating to SDV technologies were subject to one or more patent applications in Europe. The annual number of these SDV inventions, based on their earliest patent filing date in Europe, grew six-and-a-half-fold between 2000 and 2015.

The broader benchmark category of established automotive technologies corresponds to all inventions that have been classified in established technology classes for automotive technologies,[7] and thus comprises all technologies that can be found in today's mass-produced vehicles. Patent protection has been sought for a total of 298 190 such inventions between 2000 and 2015. The annual number of these SDV inventions, based on their earliest patent filing date in Europe, increased by 59% during the same period.

Approximately one third of SDV inventions have been classified in established technology classes for automotive technologies (Figure 3.1). The remaining two thirds represent technologies that go beyond the established technologies and are mainly related to information and communication technologies. Both parts of SDV technologies – those that are related to established automotive technologies and those that are not – are growing at a similar pace (Figure 3.1). This suggests that the growth of SDV technologies is largely driven by the integration of ICT with established automotive technologies.

Figure 3.1

Overlap between SDV technology inventions and established automotive technologies



Source: EPO

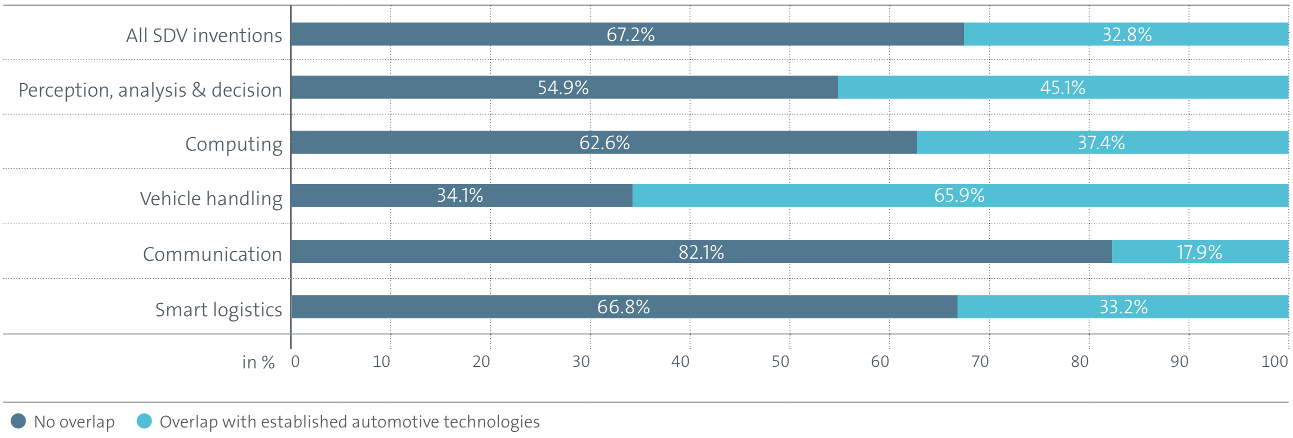
The patent statistics in this figure are based on all inventions, i.e. patent families, in established automotive technologies or SDV technologies for which a patent application has been filed in one of the official languages of the EPO, and with at least one patent application at the EPO or a patent office of a contracting state to the EPC. The reference date for each patent family is the date of the earliest patent filing at the EPO or one of the national offices of the EPC contracting states.

7 Established automotive technologies include the following technical fields and associated CPC classes: signalling and lighting (B60Q), braking systems (B60T), clutch controls (F16D48), steering & chassis (B62D), suspensions (B60G), peripherals e.g. airbags (B60R), engine exhaust (F01N), turbochargers, air intake manifolds, pistons etc. (F02B), control of engines (F02D), pistons (F02F), carburettors, fuel injection (F02M), starting of combustion engines (F02N), ignition (F02P), sparking plugs (H01T), wheels (B60B), tyres (B60C), vehicle connections (B60D), heating, cooling etc. of vehicle cabins (B60H), windows, windscreens (B60J), seats (B60N), conjoint control (B60W), transmission in vehicles (B60K).

Further confirmation can be found when looking at the same statistic for the five different SDV technology fields separately (Figure 3.2). The highest overlap between SDV and established technology inventions in the period 2011-2015 can be observed in *Vehicle handling* (66%), followed by *Perception, analysis & decision* (45%). Both technology fields are closest to the core competencies of the automotive industry. Interestingly, *Computing*, where the overlap is 37%, is not far behind. The smallest overlaps are observed in *Communication* (18%), which comprises technologies that can be regarded as the core competencies of the ICT sector, and *Smart logistics* (33%).

Figure 3.2

Overlap between SDV and established automotive technologies 2011-2015



Source: EPO

The patent statistics in this figure are based on all inventions, i.e. patent families, in established automotive technologies or SDV technologies for which a patent application has been filed in one of the official languages of the EPO, and with at least one patent application at the EPO or a patent office of a contracting state to the EPC. The reference date for each patent family is the date of the earliest patent filing at the EPO or one of the national offices of the EPC contracting states.

Computer-implemented inventions (CII) at the EPO

Inventions involving software already account for a large part of the developments in many technology areas. They represent up to 50% of patent applications in automotive technologies, and are typically observed in the field of SDVs. The EPO's approach to computer-implemented inventions provides an appropriate framework to deliver quality patents for such inventions.

In Europe, Article 52 of the European Patent Convention (EPC) excludes computer programs "as such" from patent protection. This exclusion does not mean that all inventions involving software are excluded from patenting; what it does mean is that tighter scrutiny of the technical character of these inventions is required.

Like all other inventions, in order to be patentable, computer-implemented inventions must meet the fundamental legal requirements of novelty, inventive step and industrial application. In addition, it must be established that they have a technical character that distinguishes them from computer programs "as such". In other words, they must solve a technical problem in a novel and non-obvious manner.

The normal physical effects of the execution of a program, e.g. electrical currents, are not in themselves sufficient to lend a computer program technical character, and a further technical effect is needed. The further technical effect may result, for example, from the control of an industrial process or the working of a piece of machinery, or from the internal functioning of the computer itself (e.g. memory organisation or program execution control) under the influence of the computer program.

The EPC thus enables the EPO to grant patents for inventions in many fields of technology in which computer programs make a technical contribution. Such fields include the automotive sector, as well as medical devices, aerospace, industrial control, communication/media technology, including automated natural language translation, voice recognition and video compression, and also the computer/processor itself.

The EPO has invested in its capacity to address the amount and multi-disciplinary nature of these inventions. It is crucial for staff with the relevant expertise to be involved in all the EPO's fields of operation, to ensure the consistent application of the CII content of the Guidelines for Examination in these fields. To this end, examining divisions are composed of three members with different technical backgrounds, including CII experts where appropriate. At the same time, the EPO constantly adapts its practice to the latest technology developments, including, for example, the recent rise of artificial intelligence. These are addressed through annual updates of the Guidelines, which are communicated throughout the entire EPO operational area thanks to regular peer-to-peer knowledge transfer events, e- learning modules and academy course materials.

The EPO also organises large-scale conferences such as *Patenting Artificial Intelligence* in May 2018 and *Patenting Blockchain* in December 2018 to inform applicants of its examination practice in rapidly emerging fields of digital technology. The proceedings of these conferences can be accessed on the EPO website.

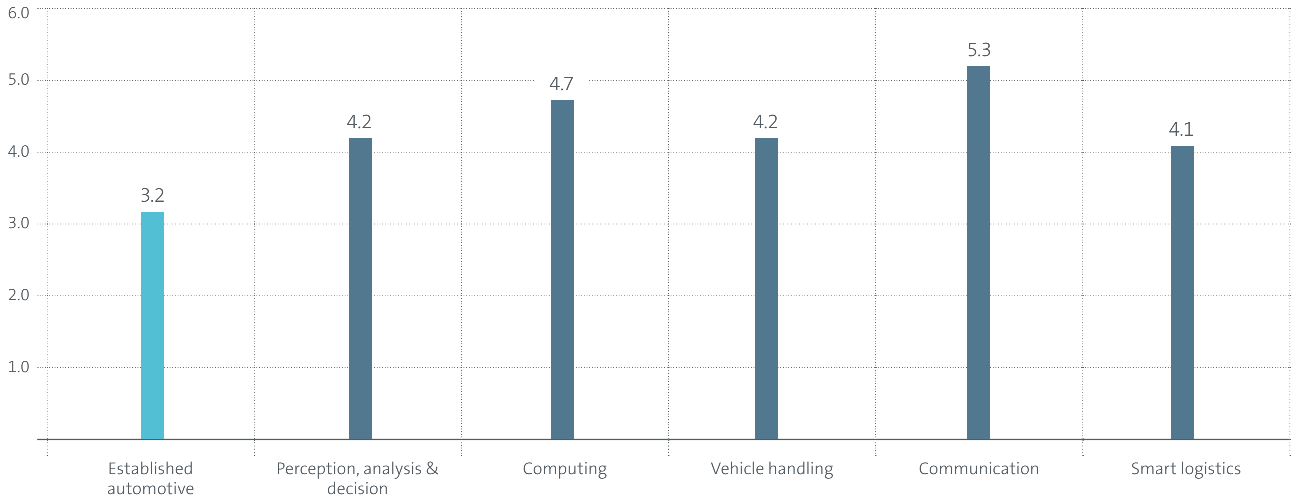
3.2 Geographical scope of patent protection

Inventions are typically protected by a set of interrelated patent rights filed in different jurisdictions (with the EPO and/or national patent offices). Together they form the patent family of the invention.[8] A comparative analysis of such patent families in SDV and established automotive technologies reveals further important differences in the geographical scope of patent protection as well as in patent filing routes.

Figure 3.3 reveals the average size of patent families (indicating the number of jurisdictions where patent protection is sought for an invention) in SDV and established automotive technologies. It shows that applicants of SDV inventions are seeking patent protection in significantly more jurisdictions. While the average size of patent families between 2011 and 2015 was 3.2 in established automotive technologies, it was significantly bigger in SDV technologies, with 4.8 applications per invention. A breakdown of SDV in its five technology fields shows that the average family size is always bigger than in established automotive technologies. However, *Communication* and *Computing*, the two technology fields which are more closely associated with the ICT sector, have significantly larger average patent family sizes, at 5.3 and 4.7 respectively.

Figure 3.3

Average patent family size in established automotive and SDV technologies 2011-2015



Source: EPO

The patent statistics in this figure are based on all inventions, i.e. patent families, in established automotive technologies or SDV technologies for which a patent application has been filed in one of the official languages of the EPO, and with at least one patent application at the EPO or a patent office of a contracting state to the EPC. The reference date for each patent family is the date of the earliest patent filing at the EPO or one of the national offices of the EPC contracting states.

8 A patent family is a set of interrelated patent applications filed in one or more countries to protect the same or a similar invention by a common inventor and linked by a common priority or priorities. This study uses the DOCDB simple patent family concept, under which all members of a patent family have exactly the same priorities.

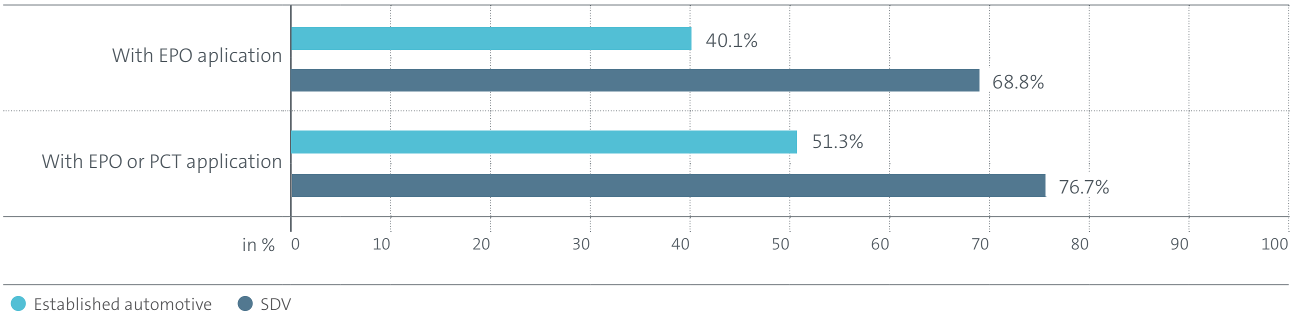
Figure 3.4 shows in turn that a much larger share of patent families in SDV technologies contained patent applications with a regional (EPO) patent office or international application using the Patent Cooperation Treaty (PCT) route.

A patent application has been filed with the EPO for almost 69% of inventions in SDV technologies, and up to 77% of SDV inventions have been filed internationally with either the EPO or via the PCT. In established automotive technologies, this proportion falls to 40% for applications at the EPO, and 51% if PCT applications are also taken into account. This means that broad international protection is usually sought for inventions in SDV technologies, whereas patent applications in established automotive technologies are primarily focused on a smaller number of national jurisdictions. This suggests that SDV applicants tend to align their patent filing strategies with the usual practices of the ICT industry.

A breakdown of SDV into its five technology fields (Figure 3.5) shows that all SDV fields have a higher share of patent families with an EPO or PCT application than patent families in established automotive technologies. The share is highest in *Communication* (80.2%) and *Computing* (74.8%) and lowest in *Smart logistics* (66.7%) and *Vehicle handling* (64.4%).

Figure 3.4

Share of European patent families with regional (EPO) or international (PCT) filings 2011-2015

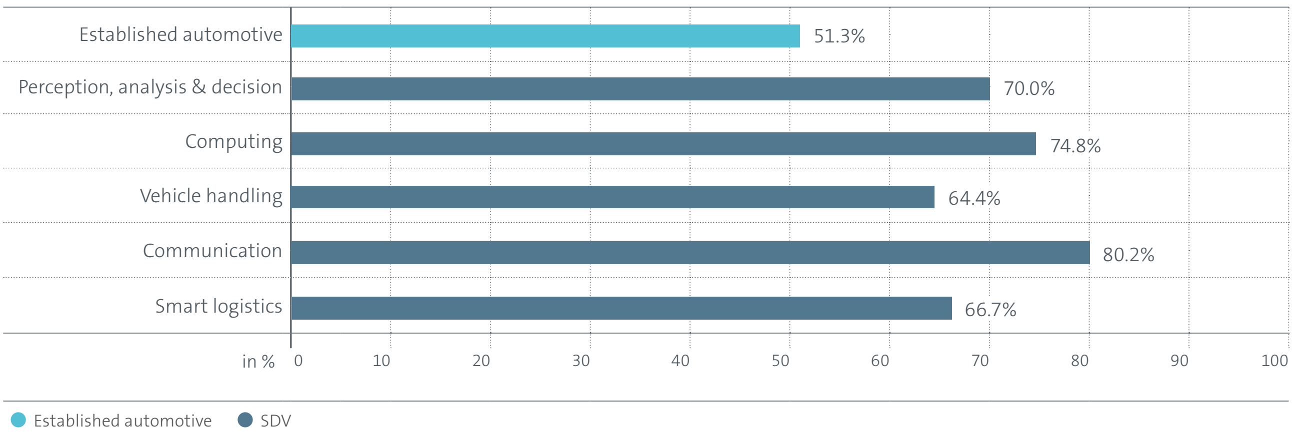


Source: EPO

The patent statistics in this figure are based on all inventions, i.e. patent families, in established automotive technologies or SDV technologies for which a patent application has been filed in one of the official languages of the EPO, and with at least one patent application at the EPO or a patent office of a contracting state to the EPC. The reference date for each patent family is the date of the earliest patent filing at the EPO or one of the national offices of the EPC contracting states.

Figure 3.5

Share of European patent families with regional (EPO) or international (PCT) filings by SDV technology field 2011-2015



Source: EPO

The patent statistics in this figure are based on all inventions, i.e. patent families, in established automotive technologies or SDV technologies for which a patent application has been filed in one of the official languages of the EPO, and with at least one patent application at the EPO or a patent office of a contracting state to the EPC. The reference date for each patent family is the date of the earliest patent filing at the EPO or one of the national offices of the EPC contracting states.

4. Patenting trends at the EPO

4. Patenting trends at the EPO

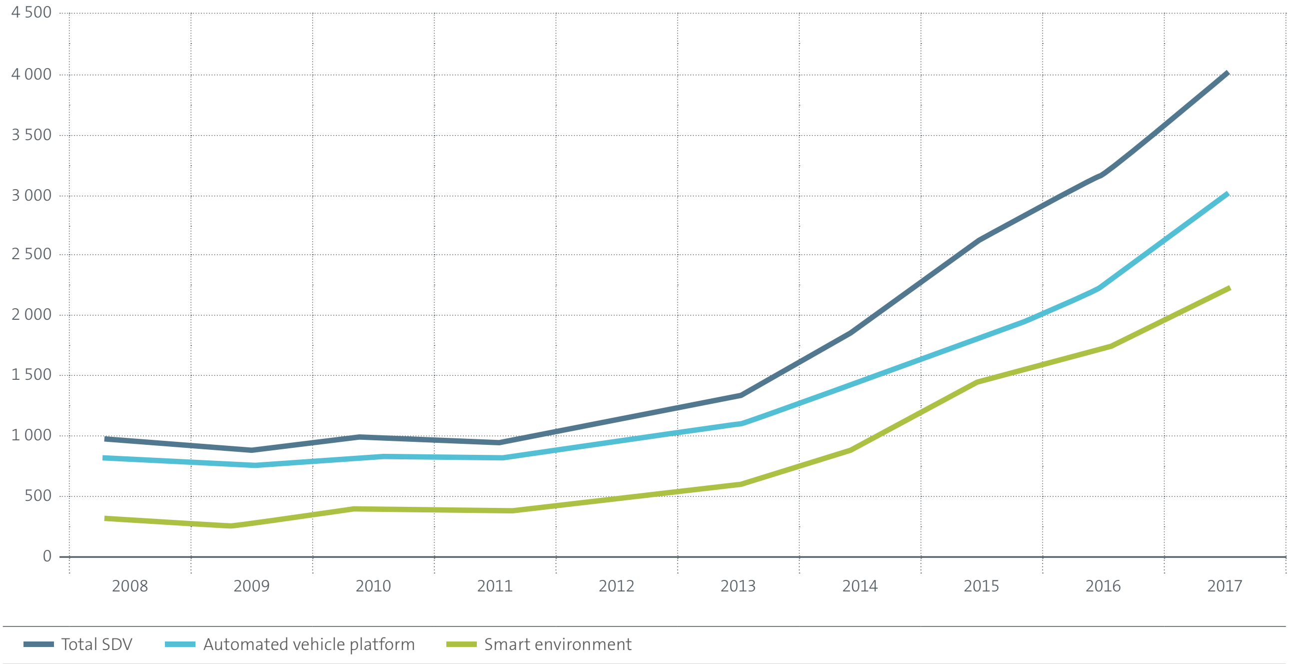
This chapter uses information from patent applications filed with the EPO to report on trends in SDV technologies up to 2017. Trends are first presented at the aggregate level. The second part of the chapter focuses on trends in the different SDV technology fields.

4.1 Aggregate trends in SDV technologies

Over the last ten years, 17 735 patent applications relating to SDV technologies have been filed with the EPO. While the number of annual applications remained stable at just below 1 000 between 2008 and 2011, it started to rise sharply in the years immediately following, reaching almost 4 000 in 2017 (Figure 4.1). Before 2012, a large majority of them were in the **Automated vehicle platform** sector. However, more recently, inventions relating to the **Smart environment** sector have been growing faster and catching up in importance. **Smart environment** technologies now comprise a greater proportion of SDV patent applications, with the ratio between applications in the two sectors going from 0.4 in 2008 to 0.8 in 2015. In total, 8 627 applications have been filed in **Smart environment** and 13 723 in **Automated vehicle platform**, whereby 4 615, or 26% of the total, can be associated with technologies in both sectors of the cartography according to their technical features.

Figure 4.1

Patent applications at the EPO in SDV technologies and their sectors 2008-2017



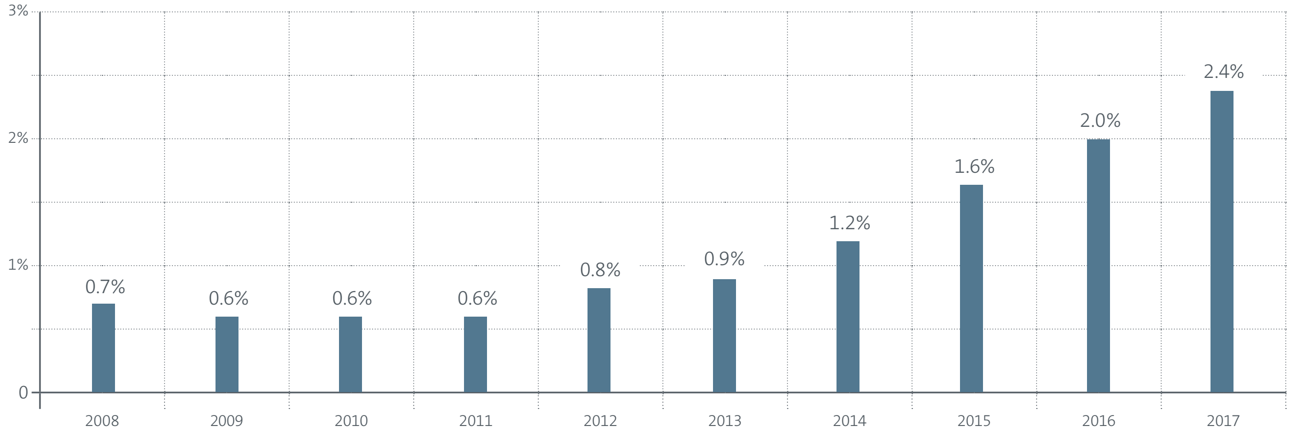
Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

The rapid increase in SDV applications means that in 2017 they represented 2.4% of all EP applications (up from around 0.6% in the years leading up to 2011) (Figure 4.2). For comparison, in a previous EPO study it was reported that the share of EP applications on smart connected objects, largely associated with the technologies of the Fourth Industrial Revolution, rose from 2% in 2011 to 3.3% in 2016.

Figure 4.2

Share of SDV patent applications in total patent applications at the EPO 2008-2017



Source: EPO

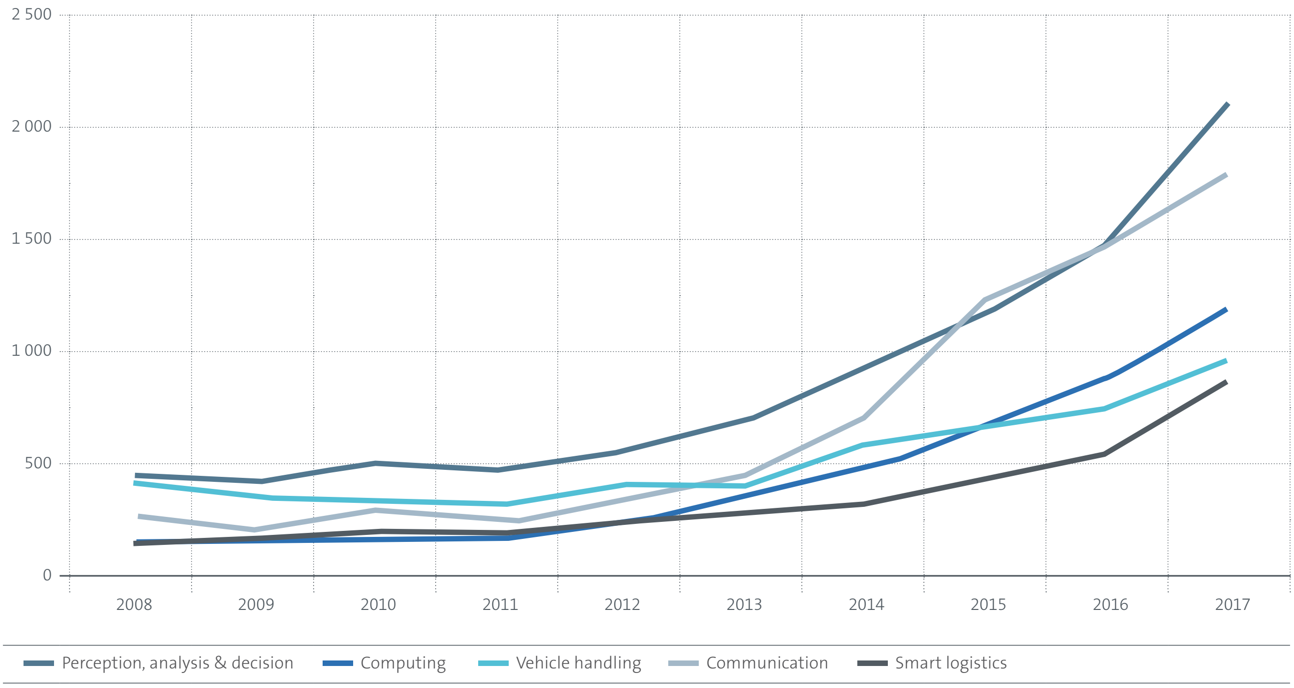
The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

4.2 Trends in SDV technology fields

In layer 2, the SDV cartography distinguishes between five larger technology fields (Table 2.1), each playing an important role for enabling fully automated vehicles. *Perception, analysis & decision* is the biggest, with 8 733 applications between 2008 and 2017, followed by *Communication* with 6 975, *Vehicle handling* with 5 163 and *Computing* with 4 515 applications. *Smart logistics* with 3 378 applications is the smallest of the five. Although all fields increased significantly between 2011 and 2017, *Communication* and *Computing* were the ones with the largest compound growth rate (Figure 4.3).

Figure 4.3

SDV patent applications at the EPO by technology field 2011-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

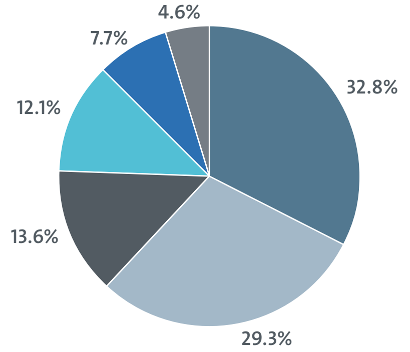
5. Applicants in SDV technologies at the EPO

5. Applicants in SDV technologies at the EPO

This chapter focuses on the profile of applicants in SDV technologies. The distribution of SDV patent applications between industries is analysed as a first step, highlighting the contributions made by established automotive industries and ICT-oriented industries to each technology field.[9] The second part of the chapter reports on the top applicants in SDV technologies.

Figure 5.1

Categories of the top 500 companies filing SDV patent applications with the EPO 2011-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

5.1 Distribution of patent applications between industries

In order to analyse the contributions of different industries to SDV patent applications, the top 500 corporate SDV applicants have been sorted into five different categories based on their main economic activity. These categories are (i) established *Automotive*, (ii) *Other transport*, (iii) *Telecommunications*, (iv) *ICT for automotive*, (v) *Machinery & electrical equipment*, and (vi) *Other*. Together, these 500 applicants accounted for 80% of SDV applications at the EPO in the period 2011-2017.

Figure 5.1 shows that *ICT for automotive* (32.8%) has the highest share in all SDV applications at the EPO, closely followed by *Automotive* with almost 30%. Companies in *Telecommunications* (13.6%) and *Machinery & electrical equipment* (12.1%) are third and fourth. These four industries can be divided into two main categories: *Telecommunications* and *ICT for automotive*, encompassing mainly large tech companies, and *Automotive, Other transport* and *Machinery & electrical equipment*, which are mostly established players in the transport sector. Applicants in these two categories contributed almost equally to innovation in SDV, with 46% and 49% respectively of all SDV inventions in the period 2011-2017.

9 The contribution of established automotive industry may be underrepresented since large vehicle manufacturers traditionally have a higher propensity to file with patent offices of contracting states to the European Patent Convention (EPC) only.

However, their contributions to inventive activity in the SDV field as measured by the shares in the five technology fields differed substantially, as reported in Table 5.1. *Telecommunications* and *ICT for automotive* companies clearly have their strengths in *Communication* and, in the case of *ICT for automotive*, also in *Computing*. By contrast, the established automotive industry has a particularly high share of patent applications in *Vehicle handling* (more than 63%). It also has strong positions in *Smart logistics* (48.7%), *Perception, analysis & decision* (44.4%) and to some extent *Computing* (33.6%). Companies in *Machinery & electrical equipment* and *Other transport* make a significant contribution to all SDV fields apart from *Communication*.

5.2 Top 25 applicants in SDV technologies at the EPO

A list of the top applicants and their strengths in the different SDV technology fields is shown in Table 5.2. Samsung, with 624 applications between 2011 and 2017, was the top SDV applicant at the EPO, followed by Intel, Qualcomm and LG, all of them major ICT companies. Robert Bosch and Toyota, two established companies in the automotive industry, follow at positions five and six. The list is completed by three more large ICT players and one automotive supplier, Continental. Many other car manufacturers and traditional automotive suppliers can be found further down the list. About half of the top 25 applicants operate in information and communication (ICT) and the other half in transport or related industries.

Table 5.1

Main applicant groups for SDV patent applications at the EPO and their technology profiles 2011-2017

	Automotive	Other transport	Machinery & electrical equipment	Telecom	ICT for automotive	Other
Perception, analysis & decision	44.4%	9.9%	13.6%	4.2%	23.8%	4.2%
Computing	33.6%	7.6%	14.4%	9.1%	30.4%	4.9%
Vehicle handling	63.4%	4.6%	15.8%	2.2%	10.8%	3.3%
Communication	18.5%	3.6%	6.9%	25.1%	42.6%	3.3%
Smart logistics	48.7%	7.0%	19.6%	5.1%	15.4%	4.1%

Source: EPO

The patent statistics in this table are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

Table 5.2

Top applicants in SDV technologies at the EPO and their profiles 2011-2017

	Company	Industry	SDV applications	Share in total SDV	Share in Perception, analysis & decision	Share in Computing	Share in Vehicle handling	Share in Communi-cation	Share in Smart logistics
1	SAMSUNG GROUP	ICT for automotive	624	4.47%	2.27%	3.39%	1.62%	6.12%	1.12%
2	INTEL CORP.	ICT for automotive	590	3.97%	0.98%	2.51%	0.32%	7.84%	0.28%
3	QUALCOMM INC.	Telecom	361	2.38%	1.28%	2.13%	1.08%	3.66%	1.81%
4	LG GROUP	ICT for automotive	348	2.42%	1.76%	1.14%	2.46%	3.66%	1.25%
5	ROBERT BOSCH GMBH	Automotive	343	2.24%	3.62%	2.94%	5.13%	1.82%	4.36%
6	TOYOTA MOTOR CORP.	Automotive	338	2.21%	3.26%	2.66%	6.83%	1.06%	3.66%
7	NOKIA CORP.	Telecom	280	1.82%	0.68%	1.14%	0.20%	3.71%	0.70%
8	L M ERICSSON A B	Telecom	264	1.77%	0.18%	0.38%	0.02%	4.10%	0.31%
9	MICROSOFT CORP.	ICT for automotive	259	1.72%	1.04%	2.86%	0.20%	2.04%	0.56%
10	CONTINENTAL AG	Automotive	259	1.71%	2.94%	1.47%	2.85%	1.93%	3.35%
11	SONY CORP.	ICT for automotive	240	1.62%	1.14%	0.94%	0.56%	2.23%	0.38%
12	BOEING COMPANY	Other transport	213	1.45%	1.95%	1.85%	0.83%	0.80%	1.46%
13	VOLVO AB	Automotive	209	1.42%	2.52%	2.30%	3.86%	0.80%	1.95%
14	GOOGLE LLC	ICT for automotive	201	1.33%	1.52%	1.27%	0.10%	1.25%	0.56%
15	PANASONIC CORP.	Machinery & electrical equipment	161	1.11%	1.47%	1.60%	1.38%	0.93%	2.13%
16	HUAWEI TECHN. CO. LTD.	Telecom	159	1.08%	0.19%	0.48%	0.15%	2.23%	0.21%
17	AUDI AG	Automotive	142	0.92%	1.64%	1.32%	2.26%	0.76%	1.71%
18	HITACHI LTD	Machinery & electrical equipment	140	0.95%	1.32%	1.27%	1.74%	0.98%	2.16%
19	SIEMENS AG	Machinery & electrical equipment	139	0.94%	0.66%	1.39%	0.96%	0.71%	1.53%
20	HONDA MOTOR COMP. LTD	Automotive	120	0.80%	1.48%	1.70%	1.60%	0.59%	1.57%
21	HERE GLOBAL BV	Automotive	118	0.83%	1.45%	0.38%	0.44%	0.93%	1.60%
22	VALEO S.A.	Automotive	113	0.79%	1.38%	0.56%	1.92%	0.37%	1.67%
23	HONEYWELL INC.	Other transport	112	0.78%	1.11%	0.58%	0.27%	0.50%	0.91%
24	BAE SYSTEMS PLC.	Other transport	112	0.72%	0.91%	0.96%	0.61%	0.19%	0.28%
25	NISSAN MOTOR COMP. LTD.	Automotive	107	0.70%	1.04%	0.81%	2.11%	0.40%	1.43%

Source: EPO

The patent statistics in this table are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

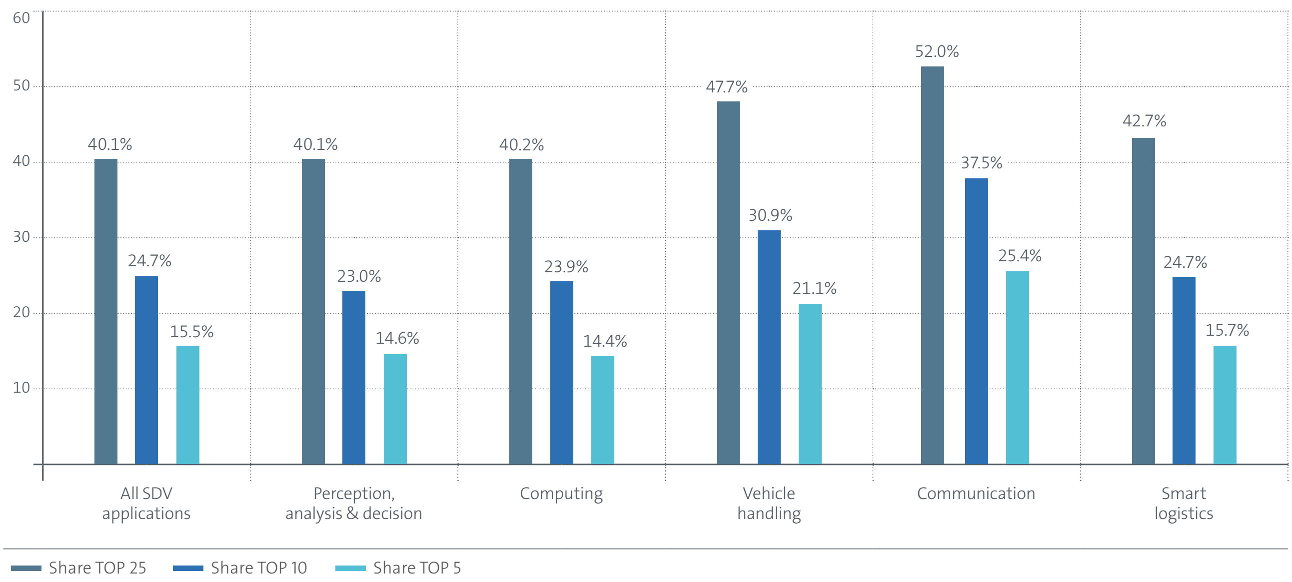
A closer look at the technology profiles of the top applicants confirms the marked differences and complementarities observed at industry level. Applicants from ICT-related industries have a strong record of patent applications in *Communication* and to a certain extent in *Computing*, and have usually made much smaller contributions to the three other SDV technology fields. This is true, for example, of Samsung and Intel, two heavyweights in semiconductors. Microsoft, a software company, has the third largest share in *Computing*. By contrast, the four largest SDV innovators from the automotive field - Robert Bosch, Toyota, Continental and Volvo - have the highest shares in patent applications relating to *Vehicle handling, Perception, analysis & decision* and *Smart logistics*.

A frequently used indicator of the stage of development of a technology market is the level of concentration of ownership of patent applications. A higher level of concentration usually signals a more mature market, while lower levels are signs of markets which have not yet been consolidated and where there is a greater level of competition between the market participants. In SDV patent applications, the top five applicants account for 15.5% of all applications, and the top ten for almost 25% (Figure 5.2). About 40% of all SDV patent applications originate from the top 25. The remaining 60% are held by hundreds of smaller technology players, demonstrating that innovation in the nascent SDV field is spread across a broad variety of actors of different sizes, industry origins and technology profiles.

These shares, which serve as concentration measures, are relatively low and stable in *Smart logistics, Perception, analysis & decision* and *Computing*, suggesting that these fields are the most open to innovation by new entrants. In comparison, *Communication*, and to a lesser extent *Vehicle handling*, show a significantly higher degree of concentration. This reflects the stronger positions of large, established applicants from the ICT and automotive industries in these two technology fields.

Figure 5.2

Share of top applicants in total SDV patent applications at the EPO and in SDV technology fields



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

6. Geographical origins of SDV patent applications at the EPO

6. Geographical origins of SDV patent applications at the EPO

This chapter analyses the origin of SDV inventions based on the geographic location of patent applicants. In the first part, all EPC states are treated as a single entity in order to compare them with the other major global innovation centres. The second part of the chapter provides more detailed statistics for European countries.

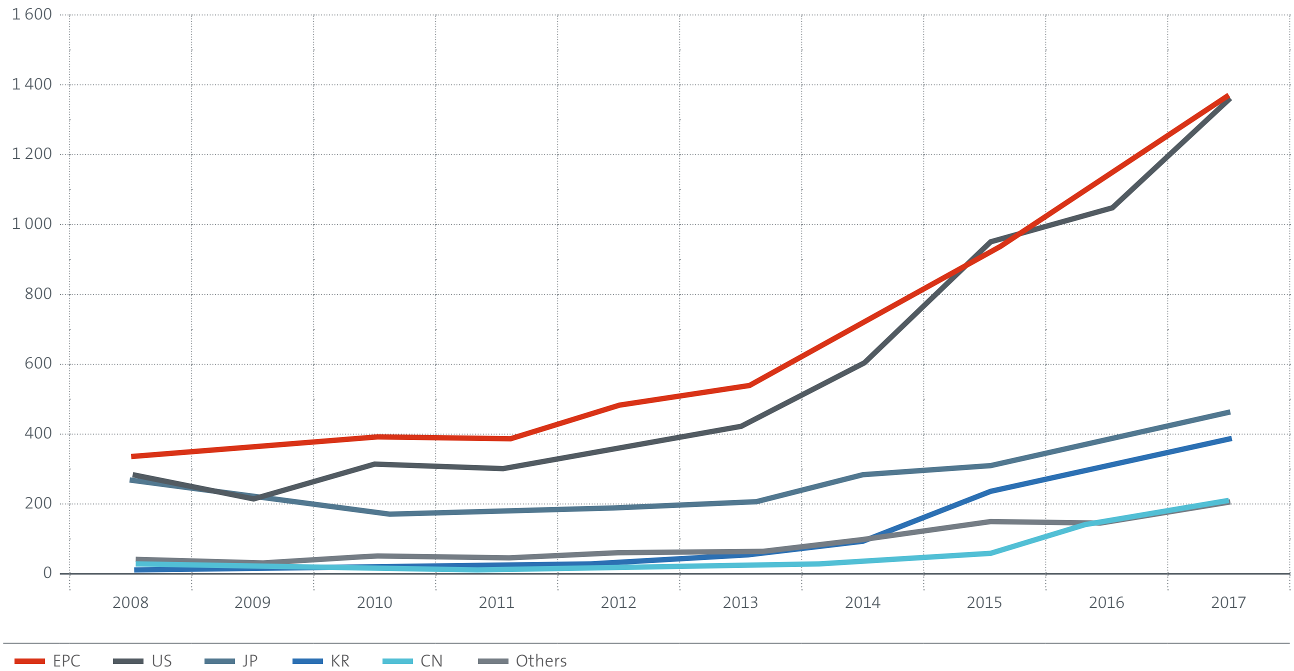
6.1 Global innovation centres

With 6 628 inventions between 2008 and 2017, European applicants contributed the highest share in SDV patent applications at the EPO, followed closely by US applicants with 5 845 applications. Japanese applicants were the third-largest contributors with 2 671 applications, less than half as many as applicants from the US. Korean applicants were the fourth largest with 1 176 applications, followed by Chinese applicants with 509 applications in the last ten years. This means that the five regions together were responsible for 95% of all SDV applications filed with the EPO in the period 2008 to 2017.

However, there is significant variation over time for all five regions (Figure 6.1). Europe (EPC) was the leading region until 2014, but the US caught up in 2015 and now the two regions are on a par. At the same time, Japan was close behind the two leading regions ten years ago, but has not been able to maintain growth since then. The Republic of Korea and the People's Republic of China, who only started to make significant contributions to SDV applications in 2013, are catching up quickly and closing the gap on Japan.

Figure 6.1

Origin of patent applications at the EPO in SDV technologies 2008-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

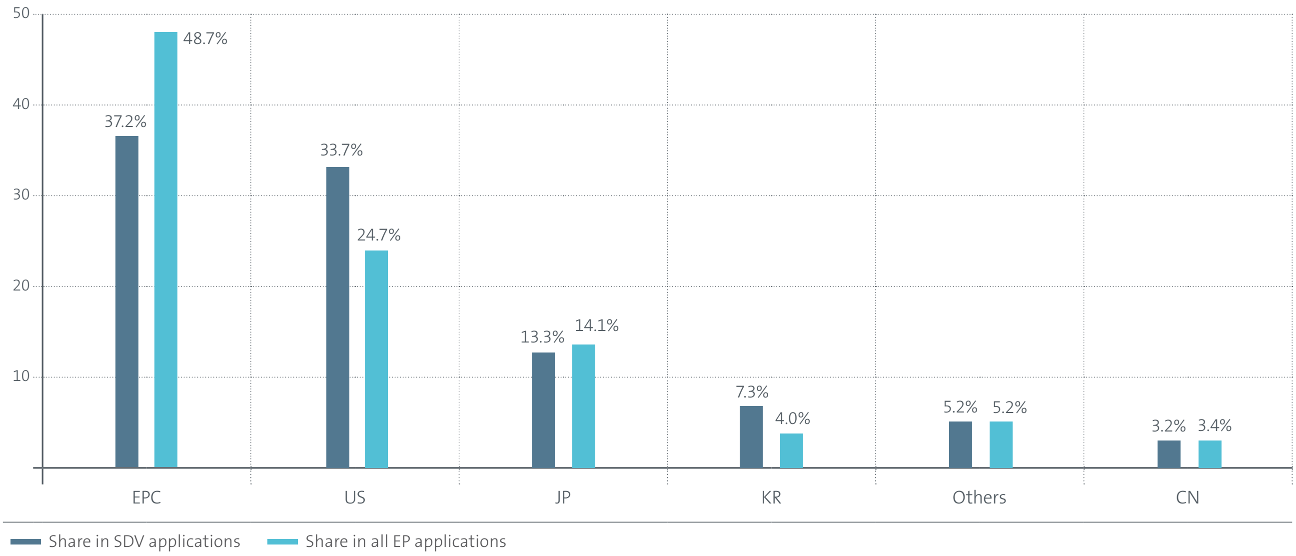
However, Chinese applicants are still only responsible for a small share of SDV inventions at the EPO (Figure 6.2), contributing just 3.2% of total SDV applications between 2011 and 2017, a figure which is only marginally lower than their overall contribution to patent applications at the EPO in the same period.

Comparing applications for SDV inventions with total applications for the other four regions reveals further interesting findings. It shows that, between 2011 and 2017, US and Korean applicants were contributing disproportionally more to SDV technology patenting compared with their total patenting activity at the EPO. For example, the share of US applicants in SDV (33.7%) was higher than their share in total patenting activity at the EPO. At the same time, Europe (EPC), with a share of 37.2% in SDV and 48.7% in total EPO applications, and, to some extent, Japan, were patenting less in SDV technologies compared with their total EPO patenting activity.

However, the aggregated view of all SDV inventions hides significant differences on the individual technology level. Table 6.1 provides a summary of the shares of the different regions in the five SDV technology fields for EPO applications between 2011 and 2017 and a comparison with the earlier period of 2000-2010.[10] It shows that European applicants were able to preserve their market share in SDV technologies in total, with a loss in *Communication*, but gains in all other technology fields. Japanese applicants recorded losses in market shares in all individual technology fields, while US applicants achieved the opposite. Since Chinese and Korean applicants only recently started patenting in SDV technology, their market shares increased in all five SDV fields compared with the period 2000-2010.

Figure 6.2

Distribution of patent applications in SDV technologies and total patent applications at the EPO by origin 2011-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

10 More detailed trends in the five SDV technology fields for the period 2011-2017 are reported in Annex 7.5.

Table 6.1

Technology profiles of top innovation regions by origin and building block 2000-2010/2011-2017

	Perception, analysis & decision		Computing		Vehicle handling		Communication		Smart logistics	
Origin	2000-2010	2011-2017	2000-2010	2011-2017	2000-2010	2011-2017	2000-2010	2011-2017	2000-2010	2011-2017
EPC	42.6%	43.5%	31.5%	36.3%	42.0%	47.0%	32.5%	30.7%	43.1%	44.2%
US	26.6%	29.3%	37.1%	38.5%	15.6%	21.0%	38.0%	38.2%	22.0%	28.2%
JP	23.2%	15.3%	23.4%	12.1%	35.8%	21.7%	19.4%	10.3%	26.1%	16.6%
KR	2.4%	4.9%	3.0%	5.3%	3.3%	5.3%	3.9%	10.5%	3.1%	3.6%
OT	4.6%	4.8%	4.5%	5.3%	2.4%	3.3%	4.5%	5.5%	5.2%	4.9%
CN	0.3%	2.3%	0.3%	2.5%	0.7%	1.6%	1.1%	4.8%	0.4%	2.5%
	100%	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: EPO

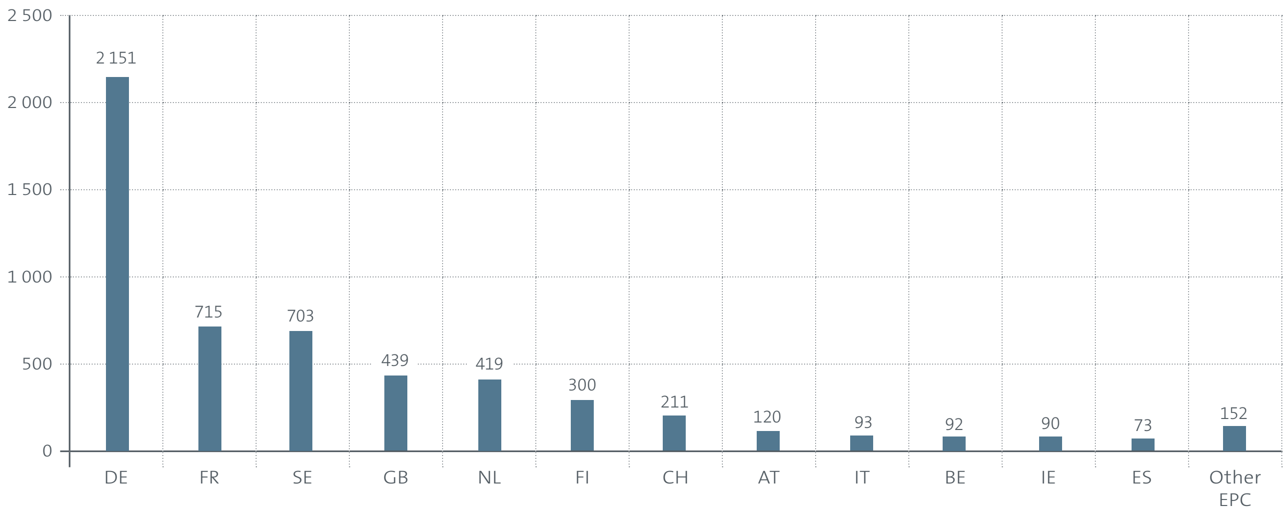
The patent statistics in this table are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

6.2 Focus on Europe

The European Patent Organisation currently has 38 member states. With 2 151 applications between 2011 and 2017 (Figure 6.3), Germany made by far the biggest contribution of all these member states to patent applications at the EPO in SDV technologies. France (715 applications, or less than a third of that of Germany) was second over the same period, followed very closely by Sweden (703). UK (439) and Dutch (419) applications complete the list of the top five European countries. Finland, Switzerland and Austria also made contributions to SDV innovation.

Figure 6.3

Patent applications at the EPO in SDV technologies by member state 2011-2017



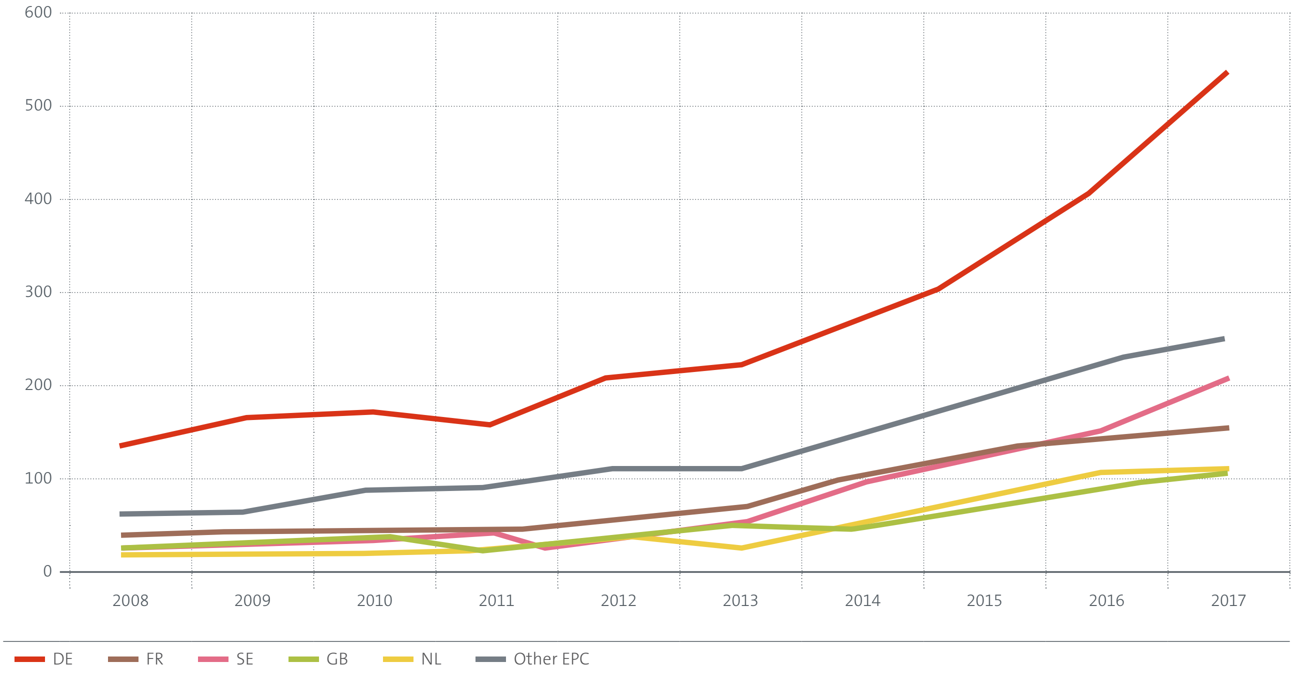
Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

The contribution of German applicants grew throughout the last decade (Figure 6.4). It accelerated after 2011, rising from less than 200 applications in 2011 to 537 in 2017. Over the last five years, applications from Sweden also experienced rapid growth, resulting in Sweden overtaking France in 2016 to become the second largest European country in annual SDV patent applications.

Figure 6.4

Trends in patent applications at the EPO in SDV technologies by the top five member states 2008-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

Table 6.2 further dissects SDV inventions by main technology field and country of origin for the top ten European countries. In addition, it allows a comparison of the respective shares with the period prior to 2011. Despite a strong increase in SDV patent applications, Germany lost market shares in SDV technologies in recent years, dropping from 17.7% in 2000-2010 to 14.4% in 2011-2017. This was mainly due to a decrease in the share of inventions in *Communication* from 12.9% to 10.3% and in *Perception, analysis & decision* from 22.5% to 19.5%. In the other technology fields, German applicants managed to hold their shares relatively stable or even increase them.

France also lost shares in overall SDV technologies between the two periods, due to significant decreases in both technology fields of the **Smart environment** sector. In contrast, the shares of Swedish applicants moved in the other direction, showing increases in all five building blocks. Dutch and Finnish applicants were also able to improve their contribution in all the main areas of SDV technologies, while Swiss and UK applicants showed a mixed performance.

Table 6.2

Technology profiles of the top seven European applicant countries

Origin	Total SDV		Perception, analysis & decision		Computing		Vehicle handling		Communication		Smart logistics	
	2000-2010	2011-2017	2000-2010	2011-2017	2000-2010	2011-2017	2000-2010	2011-2017	2000-2010	2011-2017	2000-2010	2011-2017
DE	17.7%	14.4%	21.5%	19.5%	14.3%	14.5%	25.5%	25.5%	12.9%	10.3%	21.1%	22.3%
FR	5.2%	4.8%	4.8%	4.9%	4.2%	4.5%	5.5%	5.8%	4.1%	2.4%	4.3%	2.9%
SE	2.7%	4.7%	3.9%	5.0%	2.4%	4.2%	2.8%	5.9%	2.9%	6.1%	2.6%	4.4%
GB	2.9%	2.9%	3.9%	2.9%	2.9%	4.0%	1.6%	2.8%	2.3%	1.9%	2.5%	2.3%
NL	1.4%	2.8%	1.7%	3.6%	1.3%	2.5%	0.7%	1.4%	1.5%	2.8%	2.2%	4.2%
FI	0.9%	2.0%	0.5%	0.9%	0.9%	1.4%	0.1%	0.7%	2.3%	3.5%	0.9%	1.2%
CH	1.6%	1.4%	1.2%	1.7%	2.1%	1.4%	1.2%	1.0%	1.3%	0.8%	2.0%	1.5%
AT	0.6%	0.8%	0.5%	1.1%	0.5%	0.8%	0.4%	0.9%	1.1%	0.8%	1.2%	1.6%
IT	1.8%	0.6%	2.0%	0.8%	1.3%	0.6%	2.4%	1.0%	1.6%	0.3%	2.9%	0.7%

Source: EPO

The patent statistics in this table are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

Conclusion

Main results

This study documents the dramatic rise in patent applications on SDVs at the EPO in recent years. The annual number of applications relating to self-driving vehicles rose 334% between 2011 and 2017. This represents a growth rate that is more than 20 times faster than that for patent applications as a whole at the EPO in the same period. Almost 4 000 SDV applications were filed in 2017 alone, representing 2.4% of all applications at the EPO in that year.

These trends reveal a new technical field at the crossover point between automotive and digital technologies. Up to two thirds of the underlying SDV inventions stem from technology areas that are relatively new to the automotive industry. This proportion rises to 82% for inventions in *Communication technologies*. It falls to 32% in *Vehicle handling*, the part of SDV technologies which is closest to established automotive technologies. Patent protection strategies in SDV fields also differ from those usually observed in the automotive industry and are closer to those common in the ICT sector: SDV applications are filed more frequently with the EPO or via the international PCT route, and on average span a larger number of jurisdictions.

A broad range of innovators from different industries has been actively filing such applications in recent years. Only 40% of all SDV applications at the EPO currently originate from the top 25 applicants, while the remaining 60% are distributed between hundreds of other applicants. About half of the top 25 applicants are large companies from the automotive or related mechanical and electrical industries. They have secured a strong lead in the fields of *Vehicle handling, Perception, analysis & decision* and *Smart logistics*, as well as in *Computing* technologies for SDVs. The other half consists of large tech companies, including ICT providers for the automotive field, as well as new entrants from the telecom industry. They largely dominate the field of *Communication* technologies for SDVs, and have solid patent portfolios in *Computing* technologies and *Perception, analysis & decision*. Four of them (Samsung, Intel, Qualcomm and LG Group) top the list of SDV applicants.

At a more aggregated level, the origins of SDV patent applications reveal a pattern of geographical concentration and specialisation. Since 2011, both Europe and the USA accounted for about 35% of SDV applications at the EPO, well ahead of Japan (13%), the Republic of Korea (7%) and the People's Republic of China (3%). These two leading regions exhibit different specialisation profiles, reflecting the predominance of automotive companies in Europe, and US tech companies in the USA. Within Europe, SDV innovation is largely driven by Germany. However, Sweden and France also show significant innovative activity.

Implications

This patent landscape highlights a new reality to which stakeholders will have to adapt. SDV development spans many technologies and industries, bringing together a variety of innovative companies, many of which are new to the transport sector. A few powerful automotive, software and telecom companies have developed strong patent portfolios in different sub-sectors of SDV technologies. A large fringe of smaller applicants also makes a vital contribution to innovation in these fields. In light of this fragmentation, successful growth of the SDV industry may hinge on different actors co-operating to exploit technology complementarities.

The patent system has a significant role to play in this process. Besides providing security for the development and commercialisation of SDV inventions, as the SDV industry further matures, patents will be instrumental in building new licensing and collaboration arrangements between different technology specialists. The results of the study suggest that SDV applicants have already started adapting their patent protection strategies. Significant differences do, however, persist between the automotive and ICT industries with respect to their practices in managing and utilising patents. Overcoming these differences to invent new models of collaboration is one of the challenges ahead for the emerging SDV industry.

The EPO aims to support these developments by ensuring the high quality of patents in SDV technologies in Europe. Its approach to computer-implemented inventions (CII) provides an appropriate framework for addressing the growing software content of SDV inventions in a rigorous and consistent manner across all SDV technological fields. In addition to a sector fully dedicated to ICT, the EPO also has a large Mobility and Mechatronics sector, which includes experienced CII examiners. This ensures a harmonised CII practice in SDV technologies, and more generally in all technology sectors relevant to the automotive industry.

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Annex

Annex

A.1 List of definitions and abbreviations

AAC	Adaptive cruise control
ACEA	European Automobile Manufacturers' Association
ADAS	Advanced driver assistance systems
AEBS	Advanced emergency braking systems
AI	Artificial intelligence
Applicant country	The country of the first applicant of the patent (definition used in the EPO's official reporting method for its annual statistics).
(Highly or fully) Automated vehicle technologies	This group comprises the evolution of relevant established automotive technologies as well as technologies from new automotive and ICT fields that enable the realisation of connected vehicles with a high or full level of automation and related services. It contains all technology fields as described by the cartography in Table A.1.
Automotive sector	All those companies and activities involved in the manufacture of motor vehicles.
CII	Computer-implemented inventions
CNIPA	China National Intellectual Property Administration (formerly State Intellectual Property Office of China (SIPO))
CPC class	The Cooperative Patent Classification is a patent classification system developed by the EPO and the USPTO. All patent publications are assigned at least one classification term indicating the subject to which the invention relates.
EPC	European Patent Convention
EPO	European Patent Office
EUCAR	European Council for Automotive R&D
Espacenet	Espacenet offers free access to information about inventions and technical developments from 1836 to today. With its simple search features, it is accessible to beginners and experts alike. Updated daily, Espacenet contains data on more than 100 million patent documents from around the world.
EP application	Request for patent protection for an invention filed with the EPO.
EP countries	Countries that are contracting states to the European Patent Convention (EPC).
Established automotive technologies	This group comprises all technologies that can be found in today's mass-produced vehicles which do not include the features of connectivity and automated driving. In particular, they include the following technical fields and associated CPC classes: signalling and lighting (B60Q), braking systems (B60T), clutch controls (F16D48), steering & chassis (B62D), suspensions (B60G), peripherals e.g. airbags (B60R), engine exhaust (F01N), turbochargers, air intake manifolds, pistons etc. (F02B), control of engines (F02D), pistons (F02F), carburettors, fuel injection (F02M), starting of combustion engines (F02N), ignition (F02P), sparking plugs (H01T), wheels (B60B), tyres (B60C), vehicle connections (B60D), heating, cooling etc. of vehicle cabins (B60H), windows, windscreens (B60J), seats (B60N), conjoint control (B60W), transmission in vehicles (B60K).
Filing date at the EPO	The reference date is either the filing date of the European patent application (for applications filed directly with the EPO (Article 75 EPC)) or the date of entry into the European phase (for international (PCT) patent applications (Article 158(2) and Rule 107 EPC)). This is in line with the EPO's official reporting method for annual statistics.

ICE	Internal combustion engines
ICT	Information and communication technology: the use of computers and other electronic equipment and systems to collect, store, use and send data electronically.
International patent filing	A patent filed under the PCT
Invention	New product, process or apparatus or any new use thereof. To be patentable, an invention must be novel, involve an inventive step (i.e. not be obvious to those having ordinary skill in the particular art of the invention) and be susceptible of industrial application. In this study, one patent family or one EP application is treated as one invention.
IT	Information technology
IP5	The world's five largest patent offices: EPO, CNIPO (People's Republic of China), JPO (Japan), KIPO (Republic of Korea), USPTO (United States of America)
KIPO	Korean Intellectual Property Office
Patent applicant	A person or company that applies for a patent and intends to "work" the invention (i.e. to manufacture or license the technology). The applicant may or may not be the inventor.
PCT application	International application filed under the Patent Cooperation Treaty (PCT).
Patent document	Publication of a patent application, usually 18 months after filing, or publication of a granted patent.
Patent examiner	Specialist member of patent office staff whose job it is to evaluate the patentability of inventions claimed in patent applications.
Patent family	A patent family is a set of interrelated patent applications filed in one or more countries to protect the same or a similar invention by a common inventor and linked by a common priority or priorities. This study uses the DOCDB simple patent family concept, under which all members of a patent family have exactly the same priorities.
Patent family size	Number of patent applications filed in different jurisdictions in the same patent family.
PATSTAT	EPO Worldwide Patent Statistical Database
R&D	Research and development
R&I	Research and innovation
SAE	Society of Automotive Engineers
Self-driving vehicle (SDV) technologies	See "Automated vehicle technologies"
USPTO	United States Patent and Trademark Office
V2I	Vehicle-to-infrastructure
V2X	Vehicle-to-everything
V2V	Vehicle-to-vehicle
WIPO	World Intellectual Property Organization
4IR	Fourth Industrial Revolution
5G	Fifth generation of mobile networks

A.2 SAE taxonomy of automated driving

Table A.1

Taxonomy of automated driving according to the Society of Automotive Engineers (SAE) International

Level 5 **Full automation**	Vehicles with the highest level of automation drive themselves autonomously at all times and under all conditions. Vehicle connectivity with the environment is necessary for completing the information the vehicle needs for safe autonomous driving since it does not have a steering wheel.
Level 4 **High automation**	Vehicles with **high autonomy** allow self-driving mode door-to-door. At this level, the vehicle has connectivity with the environment almost everywhere. When the vehicle is in rural areas, it can be driven autonomously and the driver would not be required to be vigilant at all. However, it may be programmed not to drive in unmapped areas or during severe weather conditions. In areas where connectivity with the environment is not available, the driver would need to be vigilant and take control of the vehicle, which will be equipped with a steering wheel. The steering wheel could possibly be stowed in the dashboard when not needed.
Level 3 **Conditional automation**	Vehicles with **conditional autonomy** are self-driving in road segments under certain traffic or environmental conditions. The vehicle is equipped with sensors that allow some environment perception and object identification that permits vehicle localisation in its immediate environment, partial decision and vehicle platform control. However, the driver must still be vigilant at all times, as the vehicle might pass control to him/her unexpectedly under certain conditions.
Level 2 **Partial automation**	Vehicles with **partial autonomy** use two or more assistance systems working in parallel, e.g. adaptive cruise control and lane keep.
Level 1 **Driver assistance**	Vehicles with **driver assistance** are based on single system assist. Multiple stability and control systems are controlled by the vehicle controller to provide a single driver assistance system, e.g. adaptive cruise control using steering, braking and powertrain management.
Level 0 **No automation**	Level 0 vehicles are vehicles which have some automatic systems which function independently of each other and, as a result, do **not allow any autonomous driving**.

A.3 Cartography of SDV inventions

The cartography scheme used in this study incorporates the technologies which will enable the realisation of a vehicle with autonomous driving capability as described by levels 4 and 5 of the SAE international standard (Table A.1). Based on the scheme, this study therefore identifies all the inventions needed to realise a reliable, safe and robust self-driving vehicle. These inventions include application-specific automotive technologies, e.g. vehicle electrification, automatic steering and braking systems, as well as general technologies, mostly from ICT (where relevant for vehicle automation), e.g. 5G networks and cloud computing technologies.

The scheme of SDV technologies in Table A.1 is subdivided into two technology sectors (layer 1). The first sector relates to technologies that build up the **Automated vehicle platform**. It encompasses technologies that are embodied in the vehicle itself. It follows broadly the functional architecture of an autonomous vehicle and comprises major functional components such as (i) perception of the external environment, object analysis, decision and control functions, together with the (ii) essential computer means for their operation, and (iii) vehicle platform manipulation functions, which are responsible for the motion of the vehicle. The second sector, **Smart environment**, is centred on the car and comprises (i) technologies that enable SDVs to communicate and interact with each other and with their surroundings, as well as (ii) technologies that enable smart logistic services and operations.

The **Automated vehicle platform** sector is subdivided into three technology fields: *Perception, analysis & decision*, *Computing* and *Vehicle handling*.

– The development of innovative sensor data fusion techniques from multiple sensors, such as long and short-range sonar sensors, Lidar, cameras and GPS sensors, is essential for perception and object analysis. These technologies assist in many tasks which are crucial for automated driving, such as precise vehicle localisation and navigation, semantic understanding (i.e. detection and identification) of moving and fixed obstacles for collision avoidance, and reliable and robust identification of vulnerable road users. Based on data collected from the environment and sensors mounted on the automated vehicle, reliable and safe navigation decisions for anti-collision purposes are taken while the vehicle platform is controlled for providing drive stability and passenger comfort. Some of the vehicle stability and control systems presented in the cartography are already used in vehicles with level 2 or 3 automation, but need further development in order to be applicable in vehicles with levels 4 and 5.

– The second technology field addresses the innovative computer-related technologies needed for guaranteeing a hacker-proof, fast-processing, multi-data-manipulating environment for automated vehicles. Upgraded computer hardware (quantum computers) and software (artificial intelligence with machine deep learning capability) will enable faster processing of the vast amount of data for decision-taking and controlling the action of the vehicle platform. The control signals sent by the vehicle "brain", comprising computer hardware and software components, to the vehicle powertrain and the brake, steering and suspension systems need to be updated around 10 000 times per second.

– The third technology field addresses the main systems used for trajectory execution by platform manipulation in an automated vehicle. It includes technologies relating to steering, braking and suspension and the different propulsion systems, such as battery electric, hybrid and efficient internal combustion engines

The **Smart environment** sector is subdivided into the technology fields *Communication* and *Smart logistics*.

– *Communication* comprises technologies that support the global connectivity of vehicles, a crucial feature for their automation. A connected car is a vehicle capable of accessing the internet, communicating with smart devices as well as other cars and road infrastructures, and collecting real-time data from multiple sources. The information exchanged between the automated vehicle and the road infrastructure may be related to traffic issues, possible navigation routes to reach a selected destination, weather conditions along the route, requests for assistance by emergency services, etc. This guarantees that the vehicle has a complete picture of the wider environment as it heads towards its destination, while its location in this complex dynamic environment is defined with a high degree of accuracy. This information can then be assessed by the vehicle in order to plan in advance for a safe, comfortable and undisrupted driving towards the selected destination. The information exchanged between vehicles further supplements the information received by the infrastructure. Since the transfer of a vast amount of data between each automated vehicle and the environment has to be fast and secure, the use of technologies such as 5G networks and compact multiple-arrays of MM-wave antennas is needed to achieve the stringent requirements for signal security in fast telecommunications networks.

– Intelligent infrastructure based on smart roads and vehicle-to-everything (V2X) communication will enable *Smart logistics*, the second main technology field of this cartography sector. Examples of such technologies are on-road assistance and delivery-on-demand services, as well as battery recharging facilities and fleet and traffic management systems.

Table A.2

Scheme of the cartography of SDV inventions

Sectors	Technology fields	Building blocks	Description and examples of technologies included
Smart environment	**Communication**	1.1.1 V2I (Infrastructure) Communication, anti-collision, infotainment, cellular network, signal encryption security	5G network; MM-wave antenna arrays technology; cloud for learning & updating high definition maps, including traffic data as well as algorithms for object detection, classification and decision-making via wireless communication
		1.1.2 Intelligent/smart roads & vehicle connectivity; wireless communication emergency & road assistance services	Devices along the route for controlling devices on the vehicle or vehicle train; special cellular communication system for vehicle application; navigation based on road infrastructure instructions; navigation based on received weather information; traffic signal arrangements responsive to adverse atmospheric conditions; data exchange to remote stations; satellite radio beacon systems; communicating vehicle information to a remotely located station; external servers for registering vehicle performance; road-embedded sensors; road-embedded signalling; solar panels with changeable LED-type road-parking markings; connection management for emergency connections (eCall); automatic toll systems using wireless information transmission between the vehicle and a fixed station
	Smart logistics	1.2.1 Traffic monitoring, traffic congestion & fleet management	Fleet management; central traffic control systems; traffic control systems for road vehicles; anti-collision external server for traffic control of road vehicles; registering or indicating the working of vehicles; recording or indicating positions or identities of vehicles or vehicle trains or setting of track apparatus
		1.2.2 Delivery on demand & automated parking	Delivery on demand; automated parking
		1.2.3 V2G (grid) connection, electricity grid, inductive battery recharging, recharging stations & roads, vehicle identification & ebilling	Inductive recharging while driving; on-road recharging; inductive charging stations (also from renewable energies); details of charging stations; service stations for exchange of batteries on electric vehicles; smart grids as climate change mitigation technologies in transport (in connection with electric and hybrid vehicles)

Sectors	Technology fields	Building blocks	Description and examples of technologies included
Automated vehicle platform	**Perception, analysis & decision**	2.1.1 Sensing (multiple sensors including lidar, sonar, radar & cameras for object & obstacle detection, classification and tracking)	Long-range radar for adaptive cruise control, emergency braking, pedestrian detection, collision avoidance & short/medium range radar for cross traffic alert, park assist with side and rear collision warning (sonar type sensors); Lidar for environment mapping, surround view, blind spot detection, park assistance; cameras for lane departure warning/control, traffic sign recognition, surround view with digital side and rear view mirror; other types of sensor
		2.1.2 Sensor fusion, semantic understanding, world model creation, localisation & navigation (data fusion including GPS data, V2V, V2I, V2E data exchange)	Navigational instruments adapted for navigation in road networks; navigation input, GPS, vehicle localisation - positioning; navigation and mapping; navigation & driving systems resulting from vehicle interaction with the environment and infrastructure; V2V (vehicle-to-vehicle) communication, platooning, anti-collision; scene perception and modelling, route selection and navigation; instruments for performing navigational calculations
		2.1.3 Driving conditions & drive assist systems, drive stability, safety & comfort	Control systems for driverless passenger-transporting road vehicles: specifically for urban driving (e.g. traffic sign recognition & GPS navigation, drive assist for drive-off & stopping, adaptive cruise control (ACC) & platooning, traffic jam assistant, traffic jam autopilot, drive assist during STOP & GO or start-stop in traffic, collision avoidance, approaching an intersection, lane assist, road markings recognition, park assist & automated parking, autonomous valet parking, rear traffic alert using backup sonar sensors and cameras); for off-road driving (e.g. road condition, drive assist for driving on winding roads, hill-assist); vehicle stability, dynamic chassis control, conjoint control of stability systems (ESP, ATC, TCS, ASR, ASC, ABS); passenger comfort, safety & security, safety assist, adaptive light control, night vision (e.g. driver drowsiness detection, driver gesture detection, tyre pressure monitoring, driver and passenger monitoring & interaction, gesture identification)
	Computing	2.2.1 Computer hardware & computer architecture	Computer architecture memory, systems, hardware, quantum computing; parallel processing & redundant systems, supervisory systems & monitoring for fault recognition & recovery; bus systems, multi-tasking, optical multiplex systems
		2.2.2 Computer software	Artificial intelligence, neural networks & fuzzy logic, genetic algorithms, deep learning, machine training; system prioritisation, supervisory systems & monitoring, fault recognition & recovery, redundant systems & parallel processing, computer security; diagnostics & fault management (monitoring autonomous system's operation, detecting faults & generating recovery solutions); energy management; trajectory generation & reactive control (decision-making, planning vehicle path trajectory & manoeuvres)
	Vehicle handling	2.3.1 Steering, braking & suspension	Automatic steering, steering assist, four-wheel steering (4WS); control-assisted steering with the steering wheel (level 4 vehicle driving autonomy); automatic steering without steering wheel (level 5 vehicle driving autonomy); active steering aids; vehicle suspension control; control systems for road vehicle drive control
		2.3.2 Powertrains (motors, ice, transmission)	Battery electric vehicles (BEV); hybrid vehicles; efficient internal combustion engine vehicles (new fuels/dual fuels/natural gas); powertrain control, electric motor control, ICE & transmission control; safety devices for propulsion-unit control specially adapted for vehicles

A.4 Identification of SDV patent applications

Since no complete patent classification scheme devoted to automated vehicles exists, the cartography was assembled from the intellectual input of patent examiners at the EPO[11] and developed and populated in the following three steps.

Step 1: Mapping the cartography to the patent classification scheme

Technology experts were asked to identify the technologies needed to enable high or fully automated driving and to group them into technology fields (layer 3), building blocks (layer 2) and sectors (layer 3) (Table A.1 for the SDV cartography scheme). Patent classification experts provided information about the field ranges of the Cooperative Patent Classification (CPC) scheme in which the inventions of the different technologies can be found. The results were used to create a concordance table of SDV technologies and CPC ranges (Table A.4). The table contains several hundred different technologies with assigned CPC field ranges in all technical fields of the SDV cartography scheme. The cartography and the assignment of CPC ranges were verified by applying ad hoc queries against the EPO's full-text patent database and analysing the results. Anomalies were re-assessed by classification experts and corrected/amended where necessary.

Example

Technology	*CPC range*	*SDV technology block*	*SDV technology field*	*SDV sector*
Vehicle control, e.g. automatic speed control	B60W30/143, B60K31/00-B60K31/185	Driving conditions & drive assist systems, drive stability, safety & comfort	Perception, object analysis, decision & control	Automated vehicle platform

11 An international patent classification scheme (IPC) for automated vehicles is currently under joint development by the EPO, USPTO, JPO, CNIPA and KIPO (the IP5 patent offices).

Step 2: Identifying SDV patent applications

Full-text search queries were applied to all published (and unpublished patent documents in the case of EP applications) in the identified CPC ranges in order to identify documents relating to the concepts of (automotive) vehicles and automated driving technologies. The emphasis was on retrieving true positives with the highest degree of certainty. Further subqueries were defined to include the concepts of artificial intelligence, cloud computing and V2X communication.

Using pure full-text queries means that the query may miss certain SDV patent documents (false negatives) and that it may match to documents which merely contain autonomous vehicle vocabulary without revealing true SDV technology (false positives). Through iterative analyses of the results and manual checks of retrieved documents, these errors have been reduced to a minimum.

Step 3: Classifying patent applications to the cartography fields

All CPC codes assigned to each identified SDV patent application during the patenting process were extracted and combined. The unique CPC classes for each application were then mapped to the respective technology fields, building blocks and sectors of the cartography using the concordance table from step 1. The combination of the cartography fields defined the characteristic SDV technology fields of the patent application.

Example

– CPC codes assigned to patent application or cited documents: B60W30/143, B60L2220/00

– Technology fields mapped to patent application: driving conditions & drive assist systems, drive stability, safety & comfort and powertrains (motors, ice, transmission)

For the purposes of this study, the statistics on SDV patent applications were based on a simple count method, reflecting the number of inventions assigned to a particular field, building block or sector of the cartography, independently of whether some of these inventions are also classified in other fields, building blocks or sectors. For example, an invention assigned to two technology fields of the same building block (sector) is counted as a single invention at building block (sector) level and as one invention in each of the technology fields. Accordingly, an invention assigned to two technology fields in two different building blocks (sectors) would be counted as one invention in each of the two building blocks (sectors) and as one invention in each of the technology fields.

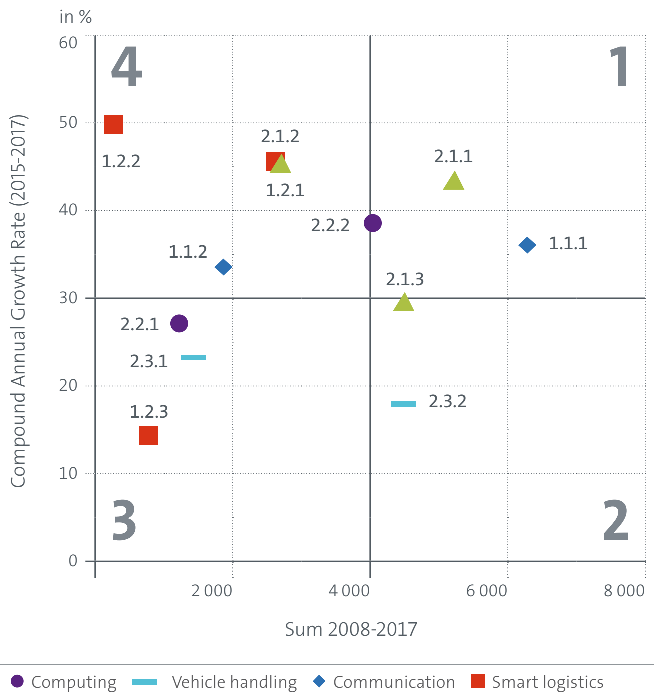
A.5 Trends in SDV patent applications at the EPO by technology building block

On the third layer, the cartography further subdivides the five SDV technology fields into a total of twelve different building blocks, with two to three blocks per technology field (Table A.1). Figure A.1 shows the relationship between the size of the SDV blocks (x-axes), measured by the total number of patent applications between 2008 and 2017 and their growth in the latest three-year period 2015-2017 (y-axes). The graph can be divided into four quadrants, such that all blocks can be sorted into those that are already large and still growing fast (1st quadrant), those that are large but have moderate growth (2nd quadrant), those that are smaller in size and growing at a moderate rate (3rd quadrant), and those that are smaller in size but growing fast (4th quadrant). The following can be observed in each quadrant:

- The **first quadrant** contains three blocks, where each block has a total size in excess of 4 000 applications and with a recent average growth rate exceeding 30%. Two of the blocks, 2.1.1 Sensing and 2.2.2 Computer software, are from the *Perception, analysis & decision* field. The third block is 1.1.1 V2I (Infrastructure) Communication, anti-collision, infotainment, cellular network, signal encryption security, which is also the biggest of all, is from the *Communication* field.
- The two technology blocks in the **second quadrant**, which are of a similar size to those in quadrant one, but with relatively slower growth, are 2.3.2 Powertrains and 2.1.3 Driving conditions & drive assist systems, drive stability, safety & comfort.
- The **third quadrant** contains technology building blocks which are smaller in size and growing slower than others. Those three blocks are 1.2.3 V2G (grid) connection, electricity grid, inductive battery recharging, recharging stations, road used for battery recharging, vehicle identification & ebilling, 2.2.1 computer hardware & computer architecture and 2.3.1 steering, braking & suspension.
- The remaining four SDV building blocks are located in the **fourth quadrant**. 1.2.2 Delivery on demand & automated parking is the smallest of all the building blocks, but is growing fastest, with a compound annual growth rate of almost 50%. The other building block in *Smart logistics* is 1.2.1 Traffic monitoring, traffic congestion & fleet management. This quadrant is completed by the SDV building blocks 1.1.2 Intelligent/smart roads & vehicle connectivity; wireless communication emergency & road assistance services and 2.1.2 Sensor fusion, semantic understanding, world model creation, localisation & navigation.

Figure A.1

Size (2008-2017) and growth (2015-2017) in SDV technology building blocks



Source: EPO

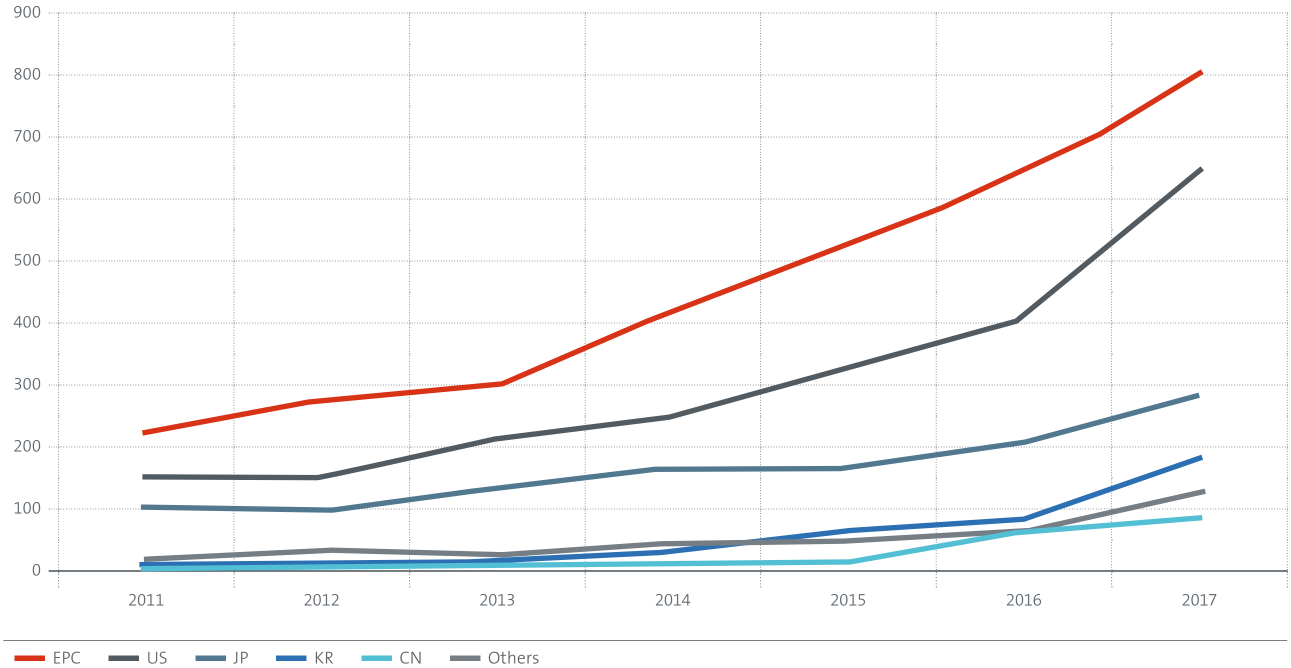
The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

A.6 Patent applications at the EPO by major innovation centre and SDV technology field

Figures A.2 to A.6 show trends in SDV patent applications at the EPO by technology field and global innovation centre. Europe (EPC) performs particularly well in SDV technology fields that are closely related to the traditional strengths of the automotive industry, such as *Vehicle handling* and *Smart logistics*, and including *Perception, analysis & decisions*. However, US applicants are catching up quickly. In 2014, Europe lost its lead to US applicants in *Communication* and the same happened in 2015 in *Computing*. Korean and Chinese applicants are strongest in inventions relating to *Communication*. Japanese applicants rank third in all technology fields, except for *Communication*, where Korean applicants have been in third place since 2015. In the same year, Japan ceded second place in *Vehicle handling* to US applicants.

Figure A.2

Origin of patent applications at the EPO in *Perception, analysis & decision* 2011-2017

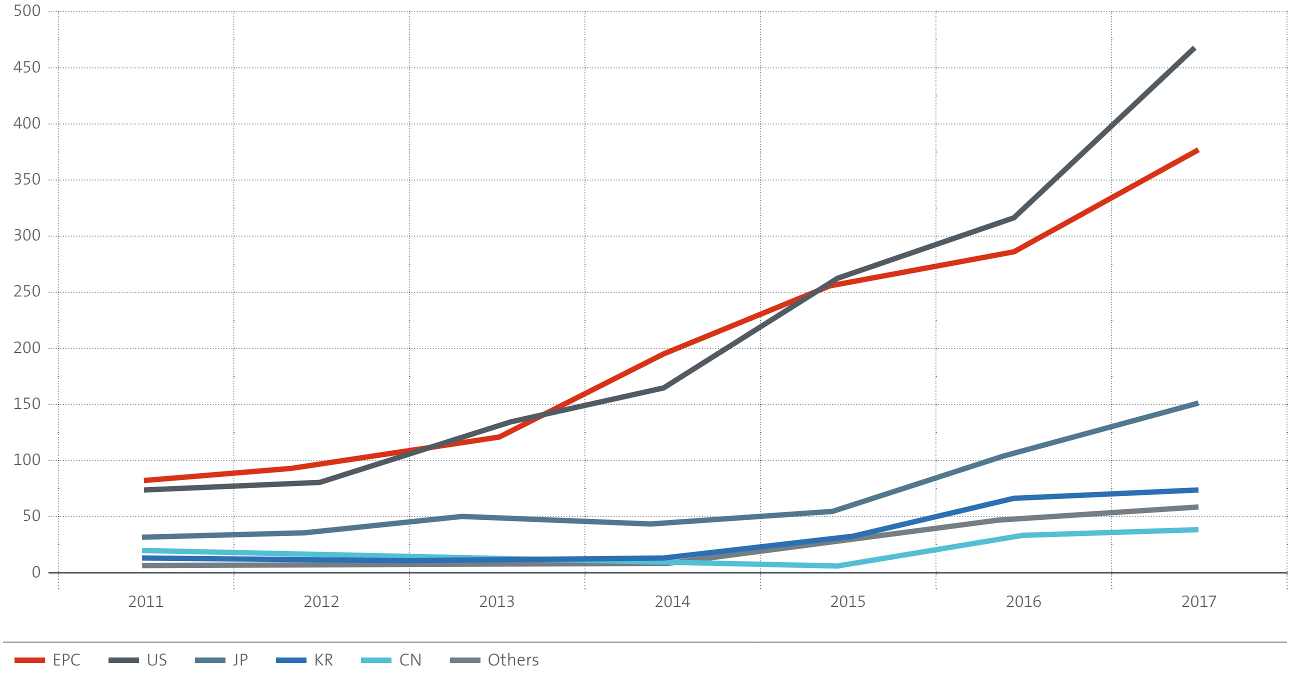


Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

Figure A.3

Origin of patent applications at the EPO in *Computing* 2011-2017

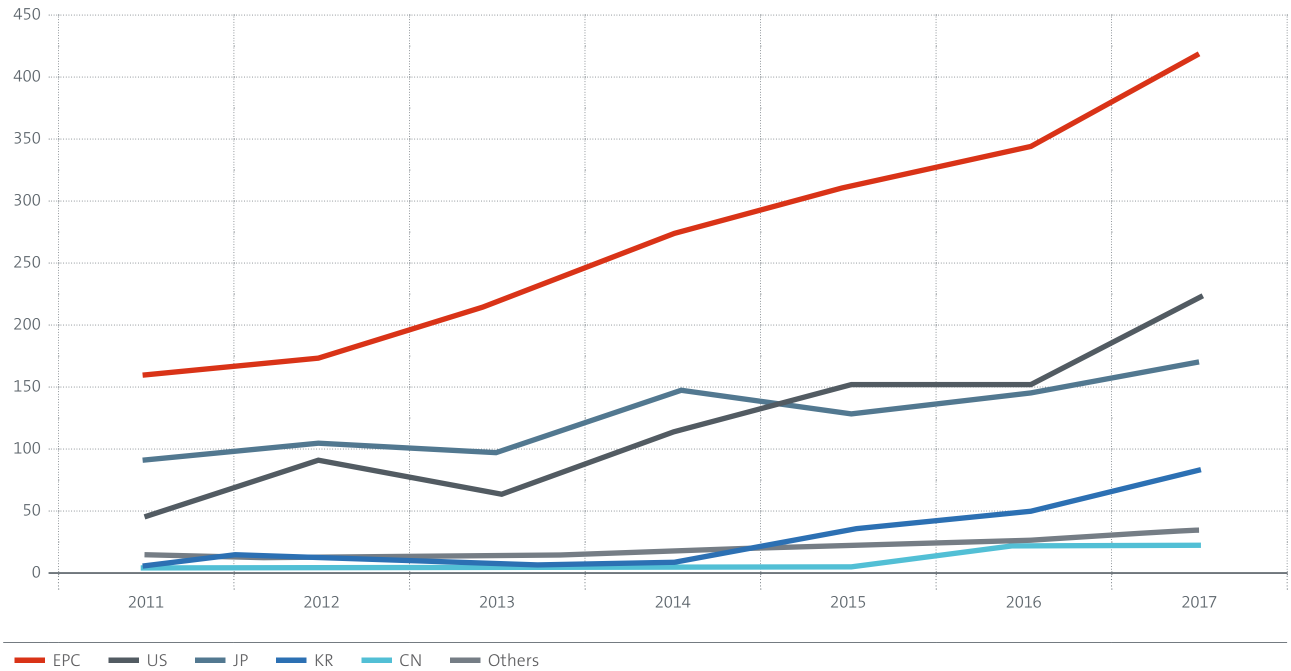


Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

Figure A.4

Origin of patent applications at the EPO in *Vehicle handling* 2011-2017

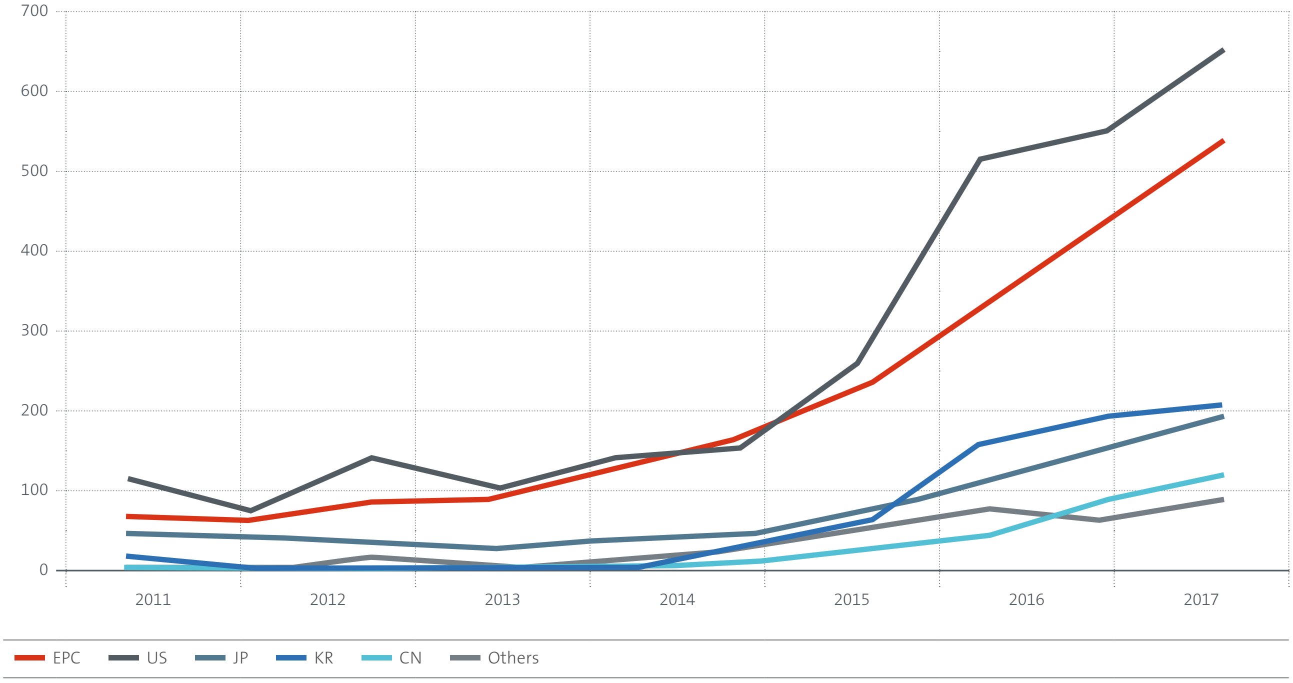


Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

Figure A.5

Origin of patent applications at the EPO in *Communication* 2011-2017

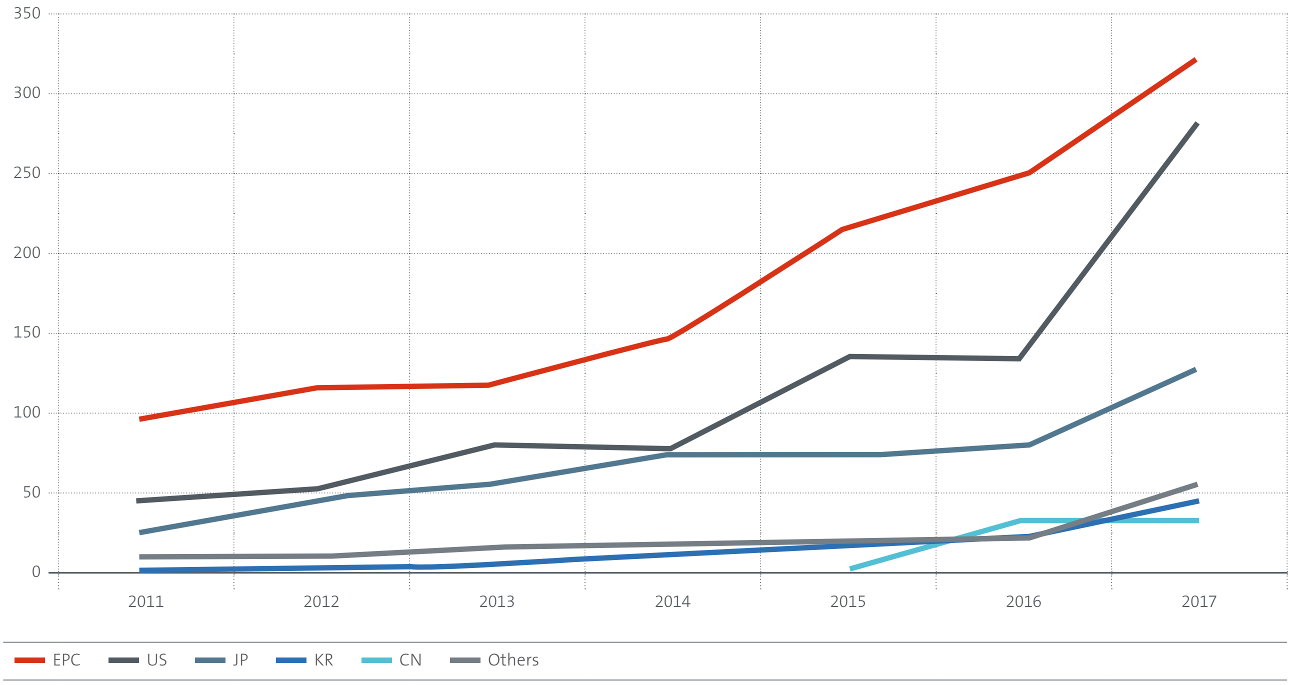


Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

Figure A.6

Origin of patent applications at the EPO in *Smart logistics* 2011-2017



Source: EPO

The patent statistics in this figure are based on patent applications filed at the EPO in SDV technologies. They do not include patent applications filed with the national offices of the EPC contracting states. The reference date for each application is the filing date at the EPO.

A.7 Patent applications at the EPO in SDV technologies by country of origin 2000-2017

Table A.3

Patent applications at the EPO in SDV technologies by country of origin 2000-2017

		2000	2001	2002	2003	2004	2005	2006
AE	United Arab Emirates							
AI	Anguilla							
AT	Austria	3	1	4	3	5	4	
AU	Australia	1	3	7	4	6	8	3
BB	Barbados							
BE	Belgium	1		4		3	2	1
BG	Bulgaria	1						
BM	Bermuda							
BR	Brazil			1				
BS	Bahamas						1	
BZ	Belize			1				
CA	Canada	3	8	6	11	13	9	6
CH	Switzerland	11	7	10	7	7	8	16
CN	People's Republic of China			2		3	2	9
CO	Colombia							
CW	Curaçao							
CY	Cyprus			1				
CZ	Czech Republic		1					1
DE	Germany	80	95	127	93	137	136	123
DK	Denmark		4	1	2		5	1
EE	Estonia							
ES	Spain	1	1	2	3		4	6
FI	Finland	2	4	10	9	6	10	3
FR	France	21	16	25	26	51	40	54
GB	United Kingdom	10	14	17	19	16	23	12
GI	Gibraltar							
GR	Greece						1	1
GT	Guatemala							
HK	Hong Kong							
HR	Croatia		1					
HU	Hungary							
IE	Ireland		1	1	2	1	1	1
IL	Israel	4	3	5	3	5	7	4
IN	India					1		
IS	Iceland					1		
IT	Italy	4	15	9	10	11	14	23
JP	Japan	142	173	151	184	197	206	177
KR	Republic of Korea	5	11	14	29	31	23	28
KY	Cayman Islands	1		1			3	1
LI	Liechtenstein		1		1		1	
LU	Luxembourg	1		1				1
MC	Monaco							
MD	Moldova							
MO	Macao							
MX	Mexico							
MY	Malaysia							
NL	Netherlands	13	3	7	9	8	8	5
NO	Norway	3		1	1	1		
NZ	New Zealand			1			1	

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Grand Total
									2	1	3
						3	1				4
2	2	9	14	12	13	17	19	16	20	23	167
6	3	4	5	6	7	10	6	9	8	17	113
			1	1					1		3
4	1	5	7	12	8	9	10	16	20	17	120
				1							2
								2		1	3
	1	1		1					1		5
											1
											1
13	14	10	25	14	29	19	35	46	37	45	343
16	8	11	21	22	18	25	18	33	52	43	333
6	8	6	9	7	16	21	41	57	145	193	525
								1			1
									1		1
2			1	2	1					4	11
	1		1	1			1	2	1	2	11
118	138	168	172	160	209	223	268	332	422	537	3 538
4	8	4	3	1	4	5	4	5	3	4	58
		1			1			1	2	4	9
7	7	5	5	2	4	7	15	20	11	14	114
4	11	3	12	13	38	32	42	42	64	69	374
48	38	44	44	43	56	72	108	133	146	157	1 122
23	30	32	35	28	36	50	48	73	93	111	670
	1										1
		1									3
										1	1
			1	1				1	2	1	6
									1		2
1	1						1	1	1	1	6
1	5	4	3	10	9	4	9	16	21	21	110
6	9	7	9	10	13	10	24	26	29	51	225
	1	1		3	3	2	11	12	23	27	84
										1	2
9	17	17	11	7	8	10	7	15	14	32	233
209	273	221	184	173	178	199	283	304	388	468	4 110
38	40	22	24	12	22	45	91	234	304	382	1 355
	2			1	1	2	3		3	7	25
	1	2	2	2				1	1	1	13
4	1	1	2	1	1	2	6		5	3	29
		1		1							2
1											1
										1	1
						1	1				2
									1	1	2
8	19	14	16	24	37	26	49	72	104	107	529
3	2		4	3	4	2	5	6	5	4	44
1	1	1	1	1		1	2	1	2	2	15

		2000	2001	2002	2003	2004	2005	2006
PA	Panama					1		
PL	Poland							
PR	Puerto Rico							
PT	Portugal							1
QA	Qatar							
RS	Serbia							
RU	Russian Federation			2	3		1	6
SA	Saudi Arabia							
SE	Sweden	9	8	13	17	16	15	20
SG	Singapore		1	1	2		1	1
SI	Slovenia							
SK	Slovakia							1
TH	Thailand					1		
TR	Turkey							
TW	Taiwan, Republic of China	1			2			
UA	Ukraine							
US	United States of America	133	118	148	182	206	210	194
VG	British Virgin Islands			1		3	2	1
ZA	South Africa					1	1	

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Grand Total
										1	2
				2	1	1	6	5	2		17
										1	1
1	1	3	2	1	1		2	6	2	2	22
								1			1
						1				1	2
	3	3	2		2		4	2	1	4	33
				1			1	4	2	4	12
13	35	28	34	41	30	52	95	121	155	209	911
1			1	1	6	6	4	4	3	12	44
	1	1									2
				1				1		1	4
											1
					1		1		2	4	8
	3	2	2	3	2	9	14	37	24	25	124
										1	1
180	279	212	313	293	361	417	607	944	1045	1374	7 216
1		1		1	1		3	1	2	4	21
	1			2					2	2	9

A.8 Concordance table between CPC fields and SDV technologies

Table A.4

Concordance table between CPC fields and SDV technologies

1. Smart environment		
1.1 Communication	1.1.1 V2I (Infrastructure) Communication, anti-collision, infotainment, cellular network, signal encryption security	G08G1/16, G08G1/164, G08G1/166, G06F21/00, H04W4/00, H04W4/44, H04W4/46, H04W12/00, H04L63/00, E01F9/00
	1.1.1.1 5G Network	H04W4/046, H04W36/0077, H04L67/12, Y02D70/126
	1.1.1.2 MM-Wave antenna arrays technology	H01Q21/00
	1.1.1.3 Cloud for learning & updating high definition maps, including traffic data as well as algorithms for object detection, classification and decision-making via wireless communication	G07C5/08, G08G1/01, G08G1/09, G08G1/091, B60L2270/40
	1.1.2 Intelligent/smart roads & vehicle connectivity; wireless communication emergency & road assistance services	G08G1/02, G08G1/0967, G08G1/0968, G01S7/003, G07B15/063, G07C5/00, G07C5/12, E01F, E01F9/00, E01F9/40, H04W36/00, H04W76/50, B61L3/00
1.2 Smart logistics	1.2.1 Traffic monitoring, traffic congestion & fleet management	G05D1/0011, G05D1/0027, G05D1/0287, G05D1/0297, G08G1/00, G08G1/01, G08G1/09, G08G1/0968, G08G1/127, G08G1/16, G08G1/164, G08G1/20, G01S13/93, G10S13/931, G01S15/88, G01S15/93, G01S17/88, G01S17/93, G07C5/00 - G07C5/08, E01F9/00, B60L2240/70, B61L25/00
	1.2.2 Delivery on demand & automated parking	G08G1/14, G08G1/22, G08G1/202
	1.2.3 V2G (grid) Connection, electricity grid, inductive battery recharging, recharging stations & roads, vehicle identification & ebilling	Y02T10/7072, Y02T10/7077, Y02T10/7088, Y02T10/7094, Y02T90/10, Y02T90/12, Y02T90/121, Y02T90/124, Y02T90/167, Y04S10/12, Y04S10/126, Y04S30/126, Y04S30/14, H02J5/00, H02J5/005, H02J7/00, H02J7/0027, H02J7/025, H02J50/10, B60L8/00, B60L11/1809, B60L11/182, B60L11/1822, B60L11/1824, B60L11/1838, B60L11/1842, B60L11/1846, B60L11/1848, B60L11/185, B60L2230/00, B60L2230/20, B60L2230/40, B60L2240/72, B60S5/06

2.1 Perception, analysis & decision	2.1.1 Sensing (multiple sensors including Lidar, sonar, radar & cameras for object & obstacle detection, classification & tracking)	G01S7/00, G01S13/00, G01S15/00, G01S17/00
	2.1.1.1 Long-range radar for adaptive cruise control, emergency braking, pedestrian detection, collision avoidance & short-medium range radar for cross traffic alert, park assist with side and rear collision warning	G01S7/00, G01S7/02, G01S7/52, G01S13/00, G01S13/86, G01S13/87, G01S13/93, G01S15/00, G01S15/025, G01S15/87, G01S15/931, G01S17/00, G06K9/00, G05D1/00, G05D1/0257, B60W2420/52, B60Y2400/3017, B60R19/00
	2.1.1.2 Lidar for environment mapping, surround view, blind spot detection, park assistance	G01S17/023, G01S17/06, G01S17/87, G01S17/88, G01S17/936, G01S7/48, G01S2013/9332, B60W2420/52
	2.1.1.3 Camera for lane departure warning & control, traffic sign recognition, surround view with digital side and rear view mirror	G06T1/0007, G06T1/0014, G06T1/20, G06K9/00362, G06K9/00785, G06K9/00791, H04N5/335, B60Y2400/3015, B60W2420/42, B60S1/56
	2.1.1.4 Other types of sensor	B60Q5/008, B60Q2300/32, B60Q2300/33, B60Q2300/45, B81B2201/02, B60C23/0408
	2.1.2 Sensor fusion, semantic understanding, world model creation, localisation & navigation (data fusion)	G01C21/00, G01C21/26, G01C21/34, G01S7/52, G01S15/00, G05D1/00, G05D1/0027, G05D1/0088, G05D1/021, G05D1/0212, G05D1/0276, G05D1/0287, G05D1/02, G06T1/0007, G06T1/0014, G06T1/20, G08G1/16, G08G1/161, G08G1/22, H04W4/44, H04W4/46, F16D2500/31, B60L2240/60, B60L2240/62, B60W30/16, B60W2050/008, B60W2550/402, B60W2550/408
	2.1.3 Driving conditions & drive assist systems, drive stability, safety & comfort	B60G17/015, B60G17/016, B60G17/0195, B60G2800/00, B60K28/04, B60W30/00, B60W40/00, F16D2500/508, G05D1/0088, G05D2201/0212
	2.1.3.1 Specifically for urban driving	B60K28/14, B60K31/00, B60Q1/00, B60Q5/006 B60R1/00, B60T2201/10, B60T2201/02, B60T7/00, B60T8/17558, B60Y2300/08, B60Y2300/14, B60Y2300/165, B60Y2300/18008, B60W30/06, B60W30/08, B60W30/14, B60W30/16, B60W30/17, B60W30/085, B60W30/095, B60W30/143, B60W30/146, B60W30/162, B60W30/165, B60W30/181, B60W30/18018, B60W30/18027, B60W30/18063, B60W30/18154, B60Y2300/06, B62D6/00, B62D15/02, F02D29/00, F16D2500/3128, F16D2500/50883, F16D2500/50866, F16D2500/50875, G01S13/00, G01S17/93, G05D1/00, G05D13/00, G06K9/00221, G06K9/00362, G06K9/00798, G06K9/00805, G06K9/00812, G06K9/00818, G06K9/00825, G08G1/00
	2.1.3.2 For off-road driving	B60T2201/04, B60T2201/06, B60L2240/64, B60Y2300/02, B60Y2300/181, B60W10/119, B60W30/04, B60W30/18009, B60W30/18118, B60W2550/14, B60W2720/40, B60G17/0165, E01F9/00, F16D2500/3124, F16D2500/3125, F16D2500/50825, F16D2500/50841
	2.1.3.3 Vehicle stability, dynamic chassis control (suspension & steering), conjoint control of stability systems	B60W10/04, B60W10/10, B60W10/20, B60W30/00, B60W40/00, B60L7/00, B60T1/00, B60T8/26, B60T8/175, B60T8/176, B60T13/66, B60T13/74, B60T17/18, B60T2201/03, B60T2201/09, B60T2270/40, B60G17/015, B60G17/016, B60G17/0195, B60G2800/00, B60Y2300/00, F16D2500/3125
	2.1.3.4 Passenger comfort, safety & security, safety assist, adaptive light control, night vision	B60C23/0408, B60R21/00, B60R22/00, B60R25/00, B60Q1/08, B60Q1/40, B60Q1/346, B60Q1/448, B60Q1/525, B60Q1/1423, B60Q2300, B60Q5/00, B60Q9/004-B60Q9/008, B60K28/00, B60K28/06, B60K2350/1028, B60K2350/1052, B60K2350/2052, B60L3/04, B60N2/002, B60W2040/0818, B60W2040/0872, B60W2040/0881, G02B27/01, G06K9/00832, G06K9/00838, G06K9/00845, G08B21/06, G08G1/005, G08G1/166, H04W4/40, H04W76/50, Y02T90/169, Y04S30/14

2.2 Computing	2.2.1 Computer hardware & computer architecture	B60W50/00
	2.2.1.1 Quantum computers: high performance, low-power-consumption systems on a chip with high reliability, robustness & hacker-proof capability	B82Y10/00, G06N99/002, G06T1/20, H04B10/00
	2.2.1.2 Parallel processing & redundant systems, supervisory systems, monitoring for fault recognition & recovery	B60W50/02
	2.2.1.3 Bus systems, multi-tasking, parallel processing, optical multiplex systems	B60R16/00, H04L12/40, H04L12/56, H04J3/06, H04J14/00, G06F8/314, G06F9/3885
	2.2.2 Computer software	B60W50/00
	2.2.2.1 Artificial intelligence, neural networks & fuzzy logic, genetic algorithms, deep learning machine training	B60L2260/40, B60G2600/1876, B60G2600/1877, B60G2600/1878, B60G2600/1879, G05B13/00, G05D1/0088, G05D1/0221, G06N, G06K9/00, G06T1/20
	2.2.2.2 System prioritisation	B60G17/0185, B60G2600/042, B60G2600/08, B60W50/02, G05B23/00, G06F8/314, G06F21/00
	2.2.2.3 Diagnostics & fault management (monitoring autonomous system operation, detecting faults & generating recovery solutions)	B60W50/02, F16D66/02, G07C5/00
	2.2.2.4 Energy management	Y02T10/72
	2.2.2.5 Trajectory generation & reactive control (decision-making, planning of vehicle path trajectory & manoeuvers)	B60W30/095, B60W50/0097, G05D1/0212

2.3 Vehicle handling	2.3.1 Steering, braking & suspension	B60K, B60L, B60T, B60W, B60G17/00, B60G21/00, B60G28/00, B62D1/00-B62D19/00
	2.3.2 Powertrains (motors, ice, transmission)	F02D, F16H, B60L15/20, B60W10/04, B60W30/18
	2.3.2.1 Battery electric vehicles	Y02T10/70, Y02T10/90, Y02T90/10, Y02T90/12, B60G13/14, B60G2300/60, B60J1/002, B60K6/28, B60K16/00, B60K2016/006, B60L, B60T1/10, B60Y2200/90, B60Y2300/18125, B60W30/18127, B60W2510/08, B60W2710/08, H02J2007, H02J5/005, H02J7, H01M
	2.3.2.2 Hybrid vehicles	B60K6, B60L, B60W10/28, B60W20, B60W2510/28, B60W2710/28, B60Y2200/92, B60Y2400/434, F02B2043/106, F02D19/0644, F02D29/00, H01M8/00, Y02T10/32, Y02T10/62, Y02T90/14, Y02T90/30, Y02T90/32, Y02T90/34, Y02T90/40, Y02T90/42
	2.3.2.3 Efficient internal combustion engine vehicles (new fuels, dual fuels, natural gas)	F01L, F02B2043/103, F02D, F16H59, F16H61, F16H63, B60Y2400/433, B60Y2400/434, B60W2510/02, B60W2510/06, B60W2510/10, B60W2510/12, B60W2710/02, B60W2710/06, B60W2710/10, B60W2710/12, Y02T10/10, Y02T10/12, Y02T10/14, Y02T10/16, Y02T10/30, Y02T10/32, Y02T10/36, Y02T90/40, Y02T90/42
	2.3.2.4 Magnetic levitation vehicles / personal mobility pods	B60L13, B61L2210/02, B61L2210/04

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