Questel

Autonomous Driving and Smart Transportation

2022 Patent landscape

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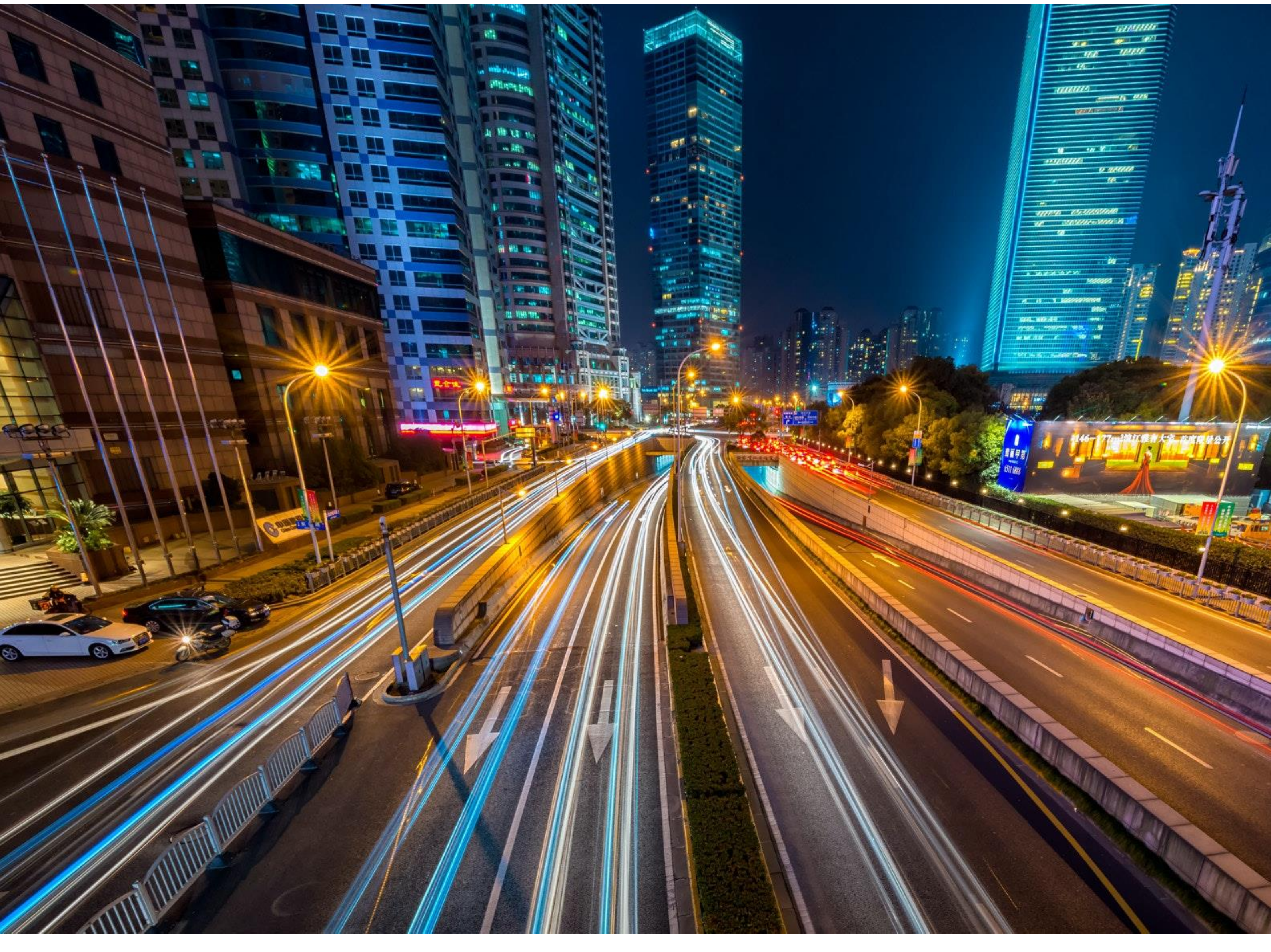

Executive Summary

An autonomous driving vehicle can operate on its own and perform the required tasks without human intervention due to its ability to sense its environment. The vehicle primarily employs artificial intelligence (AI), and multiple detection and ranging systems and navigate by forming an active 3D map of that environment. Automation of routine tasks is currently a concept that is gaining a lot of interest from several industries. With the rapid adoption of the Internet of Things (IoT), and the implementation of 5G, the global transportation infrastructure is changing rapidly. Furthermore, the rise of smart cities is bringing to life an ultra-connected infrastructure providing an ideal catalyst for autonomous vehicles. Driverless cars, trucks and buses can be intrinsically connected to vital information that reduces traffic and makes driving on the roads safer. Autonomous vehicles can interact with smart traffic lights to enable congestion-free traffic flow. Autonomous driving and smart transportation have been widely reported in recent times. Numerous market forecast surveys and patent landscapes on this topic have emerged (WIPO, EPO, McKinsey & Co, KPMG, etc.). Most of these various studies reveal a considerable growth in terms of number and size of patents and a promising assessment of the market value.

The current report has covered a global patent landscape study focused specifically on autonomous driving and smart transportation, analyzing the various trends between 2010 and 2022. This study has been divided into two main topics, Autonomous Driving and Smart Transportation. For each topic, it defines filing trends, R&D origins, market countries, key players, as well as technology segments. In addition, it uses reference information from various sources to enrich the analysis, allowing for revealing business and technological insights.

AUTONOMOUS DRIVING

A total of 49,000 patent families have been filed on Autonomous Driving-related technologies worldwide since 2010. A significant boost has been seen recently with over 75% of these applications filed since 2016, and a Compound Annual Growth Rate (CAGR) of 24% between 2010 and 2020.

The landscape shows also strong variations in the level of R&D efforts in this field between the various countries and companies.

Overall, there is a Chinese leadership in terms of patenting activity. One half of these inventions come from China, whereas only 17% of them come from the United States. Japan contributes close to 11% of total filings, followed by Germany and South Korea with 8.3% and 8%, respectively. More specifically, growth rates between 2010 and 2020 reveal a strong filing activity in Asia, with a CAGR of 32% for China, nearly 17% for Japan and 15.5% for South Korea. The

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United States shows a growth rate of 28.5% for the same period which puts it well behind China. However, a smaller ratio of granted patent families to total patent applications rate in China could mean slightly fewer high-quality inventions from China than from the United States.

In terms of geographical market, China offers a large market for autonomous driving. 64% of the patent publications were published in China, which shows its position as the leading market. This status is further strengthened by the intensity of patent filings from China. The United States comes at 28%, followed by 15% in Japan, and 12% in Germany. Nevertheless, most Chinese patent applications are published exclusively in China, and only 1.8% of Chinese applications are extended to the United States, which is the main Western market of interest for Chinese patents.

In terms of players, a significant presence of Chinese players is clearly noticed in the patenting activity of Autonomous Driving related technologies, accounting for 7.2% of global patents. The competition is tight in the top players between Chinese, Japanese, German, and American companies, which are mainly car manufacturers, companies specializing in autonomous driving, automotive suppliers and other software, telecommunications, and information technologies. The top patent filing players are led by the Chinese Internet giant Baidu, followed by the Japanese automobile manufacturer, Toyota, and Robert Bosch.

The level of aggressiveness in this field is currently low, most likely driven by the lack of maturity of the technologies. More litigation may arise in the coming years, and it will be interesting to observe to what extent the differences in leverage brought about by the respective sizes of the companies' patent portfolios may impact their future market positions.

SMART TRANSPORTATION

Concerning Smart Transportation, 35 858 patent families have been detected since 2010. The CAGR value recorded between 2014 and 2020 was 28%, a value that displays a strong position for Smart Transportation among other new generation technologies. Moreover, the landscape reveals considerable diversity in R&D levels across countries and companies.

Similar to its position for autonomous driving, China shows a strong dominance in this area as well, with 46% of global patent filings related to Smart Transportation technologies. The United States comes in second with 19%, followed by 14% for Japan, 8% for Germany and just 6% for South Korea. More importantly, China's growth rate remains steady at a CAGR of 31% from 2010 to 2020. The United States follows China with almost the same pace, with a CAGR of 30% for the same period. Meanwhile, it is worth taking into consideration the fact that South Korea has achieved a very significant CAGR of 39% from 2015 to 2020. On the other hand, the ratio of granted patent families to total patent

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applications is weaker in China than in the U.S.; from 2010 to 2018, 42% of Chinese patent applications are granted while the rate is 78% for U.S. applications. This trend could be explained by the number of revoked and abandoned Chinese patents coming mainly from academic players.

In terms of geographical market, 38% of patent families have been published in China, a number that demonstrates the importance of China as a major market. USA and Japan follow with 17% and 10% respectively. However, most Chinese players are not focused on the foreign market, as most Chinese inventions are only protected in China and only about 3.5 % of Chinese applications are extended to the United States, making it the main Western market for Chinese patents.

In terms of players, the list of top 50 shows a clear domination of companies specialized in automotive or related activities. Other players from the electronics, semiconductor, Internet, and telecommunications industries are also present. In addition, interest in the field is spread across different geographical areas with 16 Chinese (including 10 academics), 11 American (all industrial), 9 Japanese, 6 German and 4 South Korean players among the top 50. The leading patent applicant in the Smart Transportation field is the Japanese automaker Toyota with 3.6% of the global patents followed by the Chinese Internet company Baidu, with 2.8% share of inventions. The Japanese automotive manufacturer Honda came third with 1,8% and the German automobile supplier Robert Bosch ranks fourth on the list with 1,7% of the total number of patents.

As of today, the level of aggression in this field is incredibly low compared to the total number of patent families and the number of infringements in other technical domains. This number may be predisposed to increase when intelligent transportation is widely deployed. Litigation could be even more numerous as inventions are not just coming from traditional automotive manufacturers and suppliers, but also involve various technical fields such as computing and telecommunications.

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Introduction

Autonomous Driving and Smart Transportation Major Impact

Modern technologies in vehicles and transportation infrastructure are aspired to enhance the quality of life. An article of Compact[1] concerning the economic and social impacts of fully autonomous driving and smart transportation indicates that there will be two significant impacts on society:

1. There is an impact on the economy due to the reduced accident and changed travel time.
2. The new traffic system may change the professions.

In the first point, when people drive vehicles, many accidents are caused by the driver's error. The common ones are drunk driving, speeding, running red lights, and fatigued driving, and the loss caused by accidents is enormous. According to the World Health Organization, approximately 1.3 million people die yearly from road traffic crashes. A study by the NHTSA estimated that traffic accidents cost $871 billion each year, including economic damage, lost workplace productivity, and direct medical cost. These human-caused crashes can be solved by introducing autonomous driving, which according to a McKinsey report, could solve 90% of crashes. In the US, a 1% reduction in accidents can save $8bn a year, meaning stakeholders can reap substantial benefits.

Traffic congestion also contributes to economic losses. According to the global traffic scorecard of INRIX[2] , an organization measuring traffic data, people in the US waste 97 hours a year on average due to traffic congestion, which equates to a loss of $87 billion in 2018. It's worth noting that it is not sure if the introduction of autonomous driving will reduce congestion. It is often thought that autonomous driving enhances the cooperation between vehicles, so cars can better avoid crowded roads and operate more synchronously. However, introducing autonomous driving may simultaneously lead more people to travel by car. So, the impact on congestion can be either positive or negative. Carpooling services, for example, could be benefit to a large extent of the introduction of autonomous driving and help reducing the necessary fleet size.

In addition to the congestion problem, people can also use their driving time. For example, in the Netherlands, the average congestion time is one minute per person every day, but the average commuting time is 49 minutes. Therefore, autonomous driving does not significantly improve people's life in solving

[1] https://www.compact.nl/en/articles/the-economic-and-social-impacts-of-fully-autonomous-vehicles/
[2] https://inrix.com/press-releases/scorecard-2018-us/

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congestion. However, if people can effectively use the 49 minutes of commuting time, it will bring significant economic benefits to society.

In the Second Point, this report identifies the three most affected industries: workers employed in driving, servicing, and repair centers and the insurance industry. In the United States, 2.9% of people are employed in driving occupations and would lose their jobs due to the introduction of autonomous driving. Similarly, for the auto repair industry, the cost of repairs caused by car accidents is very high, already $71 billion annually in the United States. If autonomous driving can reduce the number of car accidents by 90%, it will mean the same reduction in repair costs. A 2015 KPMG study calculated that total loss costs could fall by 40% in 2040 compared with 2013. As a result, insurance premiums will fall, and insurers' earnings will change.

At the same time, with the development of self-driving cars, the engineering industry will be in high demand. According to a Friday report[1] from Boston Consulting Group (BCG) and Detroit Mobility Lab (DML), self-driving cars and electric cars will create more than 100,000 jobs in the United States in the next ten years, and 30,000 of them are engineers. Unlike the current engineering industry, the engineers needed in this industry are more interdisciplinary and require skills in mathematics, artificial intelligence, physics, big data, software, and other aspects. In addition to engineers, vehicle maintenance and remote support personnel are also needed.

Autonomous Driving

History of self-driving technology

The earliest self-driving technology dates to 1925, when Houdina Radio Control, a Radio equipment company, designed a Radio self-driving car. According to the New York Times at that time, "The driverless car will travel about the city through the heaviest traffic, stopping and starting, turning, sounding its horn and proceeding just as though there was an invisible driver at the wheel."

In the early 1990s, Dean Pomerleau, a researcher at Carnegie Mellon University, proposed using neural networks to allow self-driving cars to acquire raw images from roads in real time for directional control. He argued that the approach using neural networks is more effective than other attempts to manually classify images into "road" and "non-road" categories.

After 2015, with the rise of artificial intelligence technology, many companies began to focus on self-driving cars: In 2016, BMW and Intel announced a self-driving project, and General Motors acquired self-driving startup Cruise; In 2017, Mercedes-Benz and Bosch announced the joint development of SAE Level 4 and

[1] https://www.techrepublic.com/article/self-driving-cars-will-create-30000-engineering-jobs-that-the-us-cant-fill/

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above autonomous driving technology. Since then, autonomous cars have entered the public's vision and won more and more attention.

Five levels for autonomous vehicles

The Society of Automotive Engineers (SAE) International has defined six levels of automation – from no automation (Level 0) to full automation (Level 5)

- **Level 0**: No Automation
  This is the traditional level of driving where the full control is performed in all aspects at all time
- **Level 1**: Driver assistance
  Cars can't control steering and speed at the same time, so drivers need to assist with control and monitor road conditions and take over when the car can't drive itself.
- **Level 2**: Partial automation
  The vehicle can steer, accelerate, and brake automatically. Drivers need to interact with the external environment, such as observing traffic lights, observing the surrounding environment, changing lanes and so on.
- **Level 3**: Conditional automation
  The vehicle can drive and monitor the environment, but the driver still needs to intervene in situations where navigation is impossible.
- **Level 4**: Highly automated
  There is usually no need for human intervention and supervision. In extremely harsh or unusual environments, a take-over request is issued to the driver. If the driver does not respond, the system can automatically switch to the minimum risk state.
- **Level 5**: Fully automated
  The vehicle no longer has a steering wheel and pedals, so it can do all the driving activities without the driver taking over.

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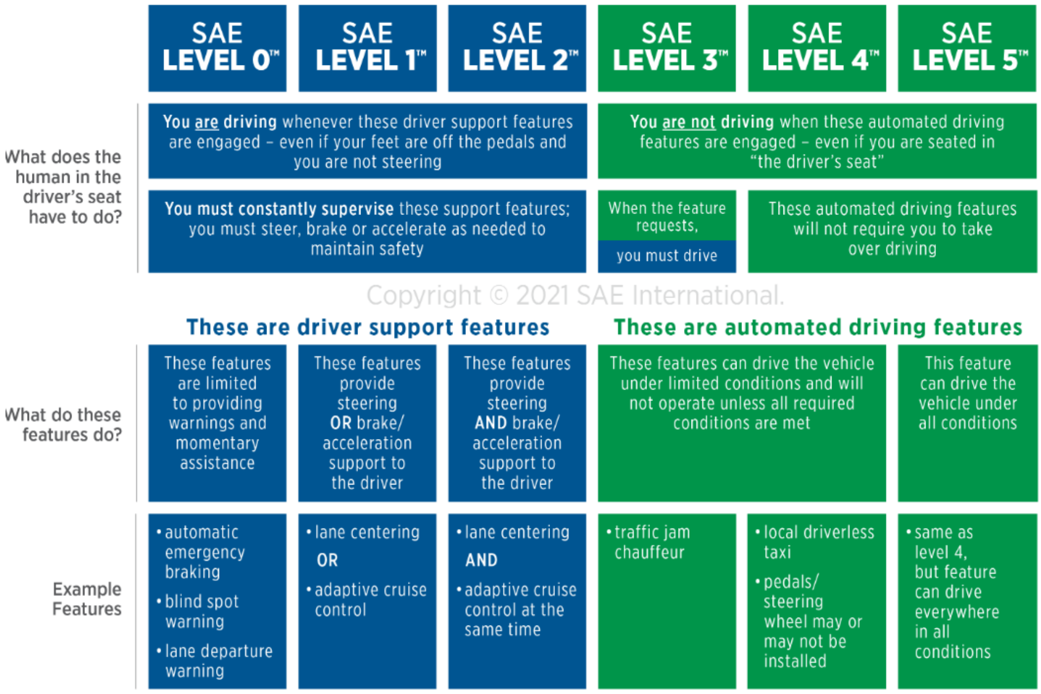

Figure 1 – SAE levels of Driving Automation

How do autonomous cars work?

Self-driving cars rely on sensors to sense external conditions. They mainly include sensors, e.g., radar, lidar, sonar, camera, an inertial-navigation system, and mapping, e.g., GPS.

Radar and lidar are mainly used for ranging, to observe nearby objects, but their applications are slightly different. Lidar mainly consists of laser emitter, receiver, scanner, lens antenna and signal processing circuit. A laser beam is fired directly over a large area for a short time, and then a highly sensitive receiver is used to map the surroundings. Lidar uses the laser to scan around things, which can detect the characteristics of objects with high accuracy, but it is unreliable in bad weather.

Radar uses radio waves to determine an object's angle, distance, and speed. The system consists of an emitter that generates electromagnetic waves, a transmitting antenna, a receiving antenna (usually the same antenna is used for transmitting and receiving), and a receiver to determine the properties of the object. Radio waves from the emitter reflect off the object and return to the receiver, providing information about the object's position and speed. It can be used over long distances or in bad weather but with relatively low accuracy.

Sonar, usually ultrasound sensors, generates sound waves and use echoes to determine distance from objects without relying on the light. However, the receivers may get interferences or lose signal, making this solution somewhat unreliable.

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Camera can be used to capture the external environment and obtain high-resolution images. Cameras usually include lens, image sensor, image signal processor, and serializer. The image sensor processes the basic information collected by the lens and then submits it to the processor for serial transmission. However, the disadvantage is that it only works in good weather conditions and can only capture visible visual data.

Inertial navigation systems can detect the physical movements of cars to help them stabilize themselves and decide which safety measures (such as airbags) to employ in emergencies. The inertial navigation system is completely independent; it neither transmits nor receives signals from the outside. An inertial navigation system must know exactly where it is at the beginning of the navigation and then estimate the change in position.

GPS can detect the location information of cars and combine it with maps for navigation. The satellite sends a signal to the receiver, and the distance can be calculated by the time and the speed of light. The location can be calculated according to four satellites. However, due to the low accuracy of GPS, particle filtering can be used to improve location accuracy.

Smart transportation

An intelligent transportation system includes not only the smart vehicles, but also intelligent public infrastructure comprising interaction with road equipment, traffic lights, and processing and analytical services from network-based modules or devices. Smart transportation benefits from the proliferation of the Internet of things and 5G services. It takes advantage of those technologies to connect, coordinate and adjust exchange between vehicles, and vehicles and infrastructure making a better use of resources in the city while reducing accidents.

It is a technological field arousing investments interest. The growth is driven by increasing innovative city projects and government programs around the world. Smart transportation systems simplify and enhance traffic management safety and facilitate the use of intelligence in modern transportation networks.

Autonomous driving and smart transportation landscape: A need

The success of autonomous vehicles includes the development of various technologies, such as automatic emergency braking, the Internet of things, 5G, automotive lidar, V2V, software development, HD maps, image recognition, traffic information recognition, as well as the support of the network.

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Since the development of these technologies requires the protection of patents, the number of relevant patents can reflect the development of the industry and the degree of attention.

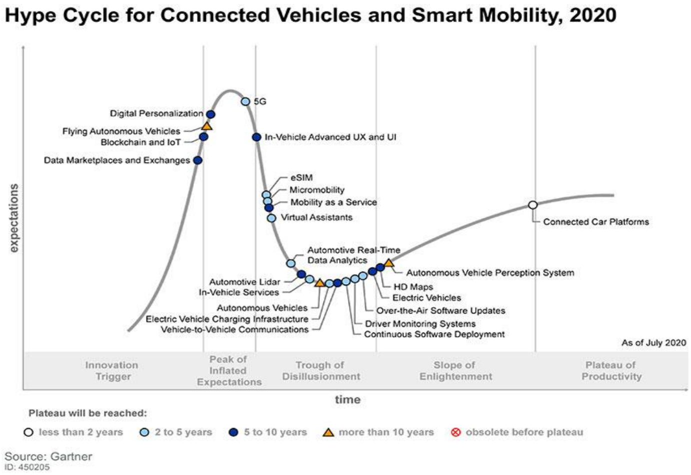

Figure 2 – Hype cycle for connected vehicles and smart mobility, 2020

According to the 2020 hype cycle[1], the IoT and 5G technology closely associated with smart transportation are at the peak of expectations, indicating that the technology is in the rising stage and companies will face fierce competition. Some companies will be eliminated from the market. Technologies related to self-driving cars, such as lidar, electric vehicles, V2V, and software, are at the trough of disillusionment phase. Due to the lack of competitiveness, many companies are already out of the market, while the rest need to overcome the problems and adjust their strategy to enter the slope of enlightenment stage.

It is necessary for companies involved in these technologies to align their IP strategy to protect their products and designs. Therefore, studying the patent landscape is a need to better understand the development status and future trends of autonomous driving and smart transportation.

[1] https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/documents/Gartner-connected-vehicles

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Methodology

Patents search strategies

Data source

The data source used in this study is FamPat worldwide database search tool Orbit Intelligence. FamPat is a global collection of patent applications and granted patents organized by simple patent families, covering more than 100 patent authorities all over the world, including searchable full text from 63 patent offices, provided by Questel.
As each Fampat record contains potentially many individual publication events all with different dates, the report uses the earliest known office of first filing date for each patent family. This is considered as the representative patent family member which is being used to refer to the patent family. The office of first filing (OFF) or priority, refers to the first application for a particular invention which, when filed at any patent office becomes the "priority application", with the date of this event defining the priority date. The country of the first filing is defined as the first priority country.

The tables and charts included in the report use this priority date, unless otherwise noted, because it provides the most accurate indication of the inventive activity. The definition of patent sources, i.e., the location from which patent families are emanating, is based on the Office of First Filing (OFF). It should be noted that this definition is not 100% accurate, nevertheless, it provides a useful and fair method of identifying the usual country of first filling of entities, which typically coincides with their home patent office.

As mentioned previously, the current study focuses on Autonomous Driving and Smart Transportation technologies, major elements in the new technological revolution.

The search was performed by employing several strategies, using Autonomous driving, Smart Transportation, and their associated techniques keywords as well as relevant patent classifications (such as B60W60/00: drive control systems specially adapted for autonomous road vehicles). The relevance of the results is guaranteed between exhaustivity and accuracy thanks to the proper use of Boolean operators and an iterative search process.

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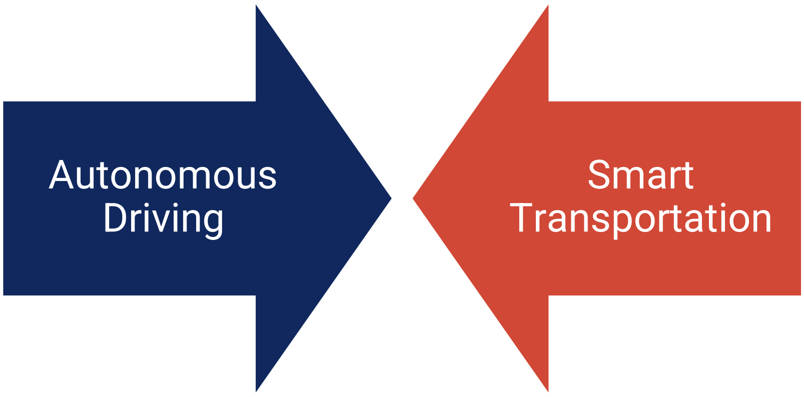
Taxonomy

Studied areas

As interaction between public infrastructure and the automotive industry is at the core of intelligence in the transportation industry, this patent landscape will study both technical fields Autonomous Driving and Smart Transportation for the sake of a more comprehensive view.



Focus will be on upper levels of vehicle autonomy (SAE Level 4 and Level 5) where human intervention is minimal or totally absent.

Definition of the taxonomy to segment the patent dataset

As stated previously, the study was conducted on two different axes:

- **Autonomous Driving:** Focusing on the autonomous driving high-level intelligence features of vehicles
- **Smart Transportation:** Aiming the intelligence in the evolved transportation systems and infrastructure

Both technical fields contain a wide range of concepts. The analysis was performed on both subjects' general aspects with a more focused study on different segments. The selection of segments' subjects was based on their importance to the fields and on their high contribution in the actual R&D activities. However, this selection is not exhaustive; developments and innovation are also taking place in other domains such as communications, Artificial Intelligence, and others.

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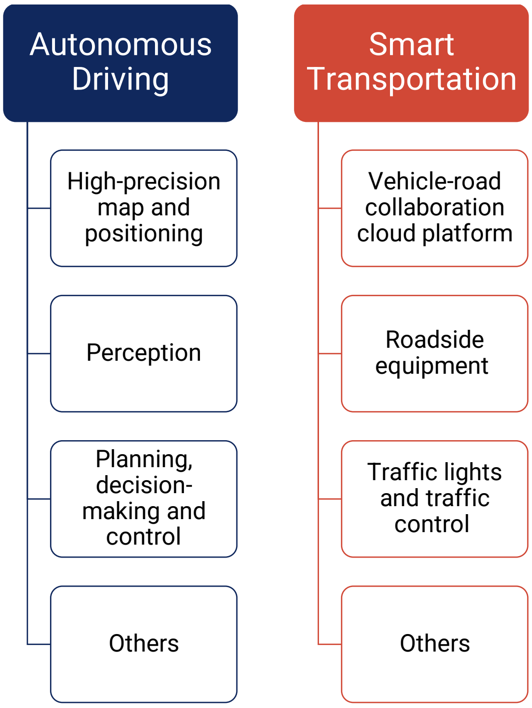

Autonomous Driving:

- **High-precision map and positioning:** High-precision positioning, over-the-horizon sensing, lane-level path planning, and other services provided by the high-precision map
- **Perception:** Sensing technology relying on sensors (lidar, cameras, and radar) and massive centralized computing
- **Planning, decision-making and control:** Path planning, decision-making and motion controlling technologies
- **Others:** Other technologies such as connectivity and data transmission

Smart Transportation:

- **Vehicle-road collaboration cloud platform:** Cloud computing traffic related services
- **Roadside equipment:** Intelligent driving roadside devices used to assist vehicle driving
- **Traffic lights and traffic control:** Intelligent traffic lights processing traffic information and managing Intersections' traffic congestion and traffic overflow
- **Others:** Other technologies part of the development of Smart Transportation

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Patent landscape

Autonomous Driving

Filing trends

A rise in growth

The period of analysis for this report was limited to the period from 2010 to October 2022. 48,869 patent families related to autonomous driving were detected during this period.

The trend of technology investment over the last few years, namely from 2010 to 2020[1], is illustrated by the graph below, which clearly shows the increase in patenting activity:

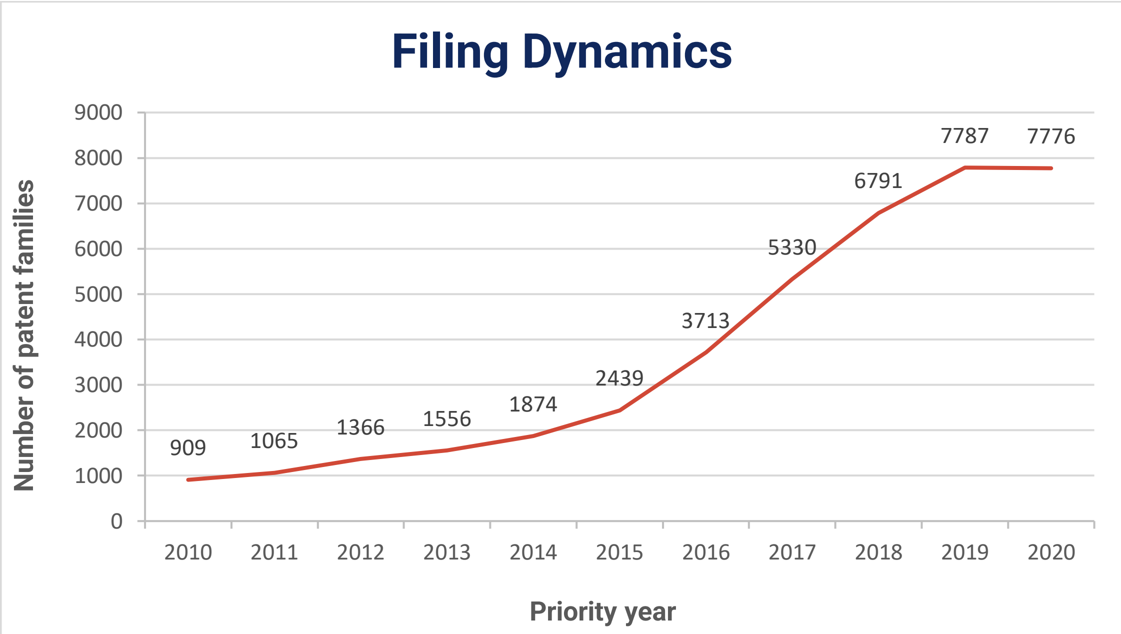

Figure 3 – AD Filing dynamics

Patent applications for autonomous driving are experiencing an acceleration in the number of new filings since 2010. The CAGR* of up to 24% between 2010 and 2020 indicates that this field is expanding rapidly. In addition, many new patent filings are expected in the coming years (many of which are still unpublished).

[1]Due to the delay between the priority filing of a patent and its publication by patent offices, usually 18 months, the last complete year of information used in the current report is 2020.

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Patent landscape

Autonomous Driving

Inventions' origin

Nearly half of all patent filings belong to China

Priority country data relates to the amount of patent families which was first filed in a country. It usually contains information on the patenting strategy in the sector and is a strong indicator of the main R&D locations, as most players apply for priority patents locally.

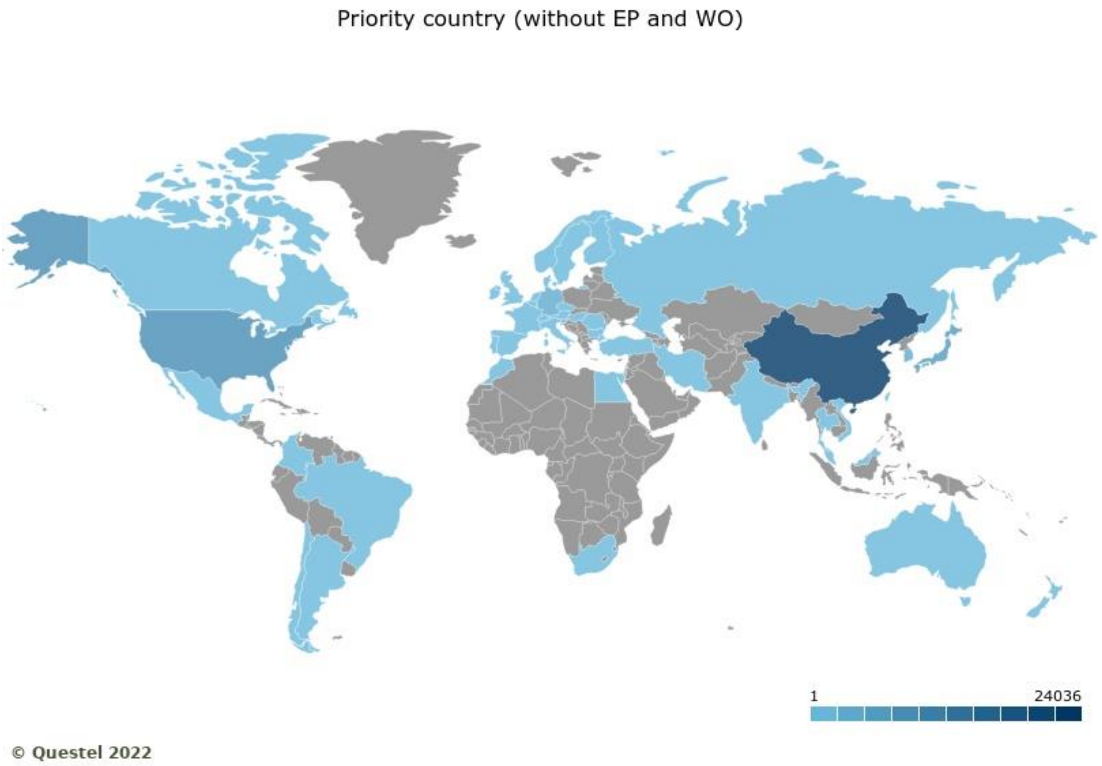

Figure 4 – AD Worldwide patent families by priority country

Overall, about 49.18% of the autonomous driving-related patent applications filed worldwide over the past 10 years came from China, whereas only 17% were from the United States. Japan contributed with 10.9% of the total filings, followed by Germany and South Korea with 8.3% and 8%, accordingly.

In 2010, China's patent applications represented 28% of global patent filings; by 2020, half of autonomous driving-related patent applications came from China; and by 2021, this percentage exceeded two-thirds, about 78%.

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From 2010 to 2020[1], a significant gap between China and other parts of the world was observed. From the start of this study period, China's patent applications have surpassed those of the United States, Japan, Germany, and South Korea. This field has been led by Chinese applicants with a continuous increasing disparity, reaching more than twice the patent applications (almost twice the patent families granted) compared to America between 2010 and 2020. Nevertheless, a lower ratio of granted patent families to total patent applications is noted for China compared to the United States, where only 35% of Chinese patent applications were granted while 86% of U.S. applications were granted between 2010-2018. The comparison is limited to 2018 as the drop in ratio value observed in the graph starting from 2019 could be misleading, as the patents may still be under examination.

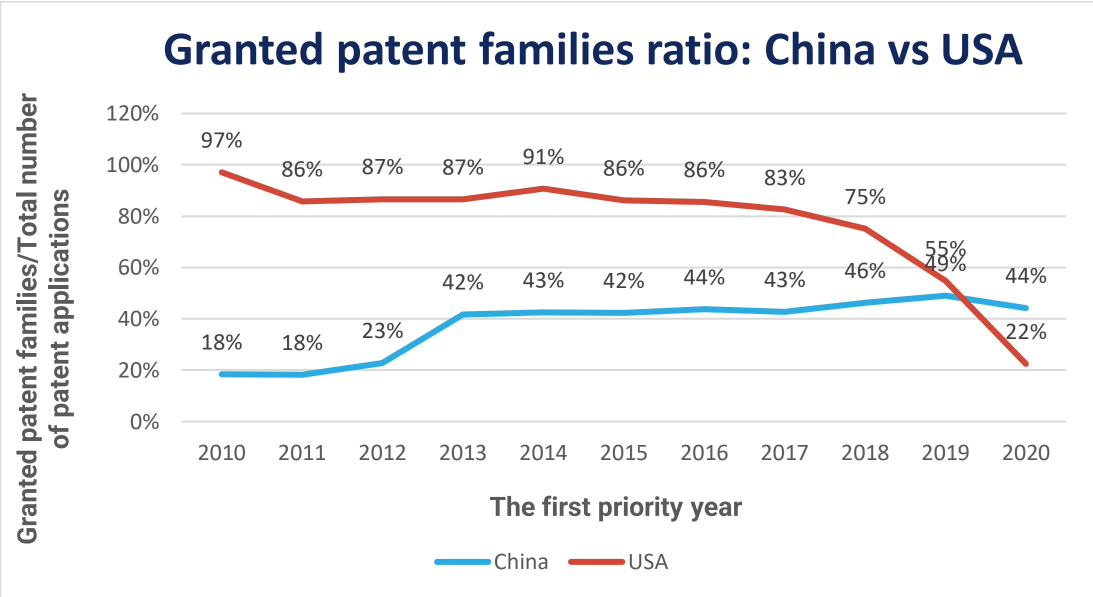

Figure 5 – AD Granted Patent families ratio: China vs USA

The annual mean contribution of Chinese patent applications to global patent filings was about 38% for the period 2010-2020, led by 78% for 2021 as the highest annual contribution and by 28% for 2010 as lowest annual contribution; meanwhile, the United States, the second largest country, accounted for only 18%. The strong contribution of China could be linked to, firstly due to the improvement of wireless networks (5G) and the increasing implementation of the Internet of Things (IoT), and secondly, according to Pandaily[2] Beijing-based media company, since Major Chinese cities are adopting autonomous driving-friendly policies and embarking on autonomous driving trials, to be ready to accelerate its commercial use. By 2025, the city of Shanghai will build a leading domestic innovation and

[1] Due to the delay between the priority filing of a patent and its publication by patent offices, usually 18 months, the last complete year of information used in the current report is 2020

[2] https://pandaily.com/chinas-first-tier-cities-introduce-favorable-policies-for-autonomous-driving-field/

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development system for internet-connected vehicles, and the industry scale will strive to reach 500 billion yuan ($69 billion). As reported by Autonews.fr[1], several pilot projects for highways dedicated to autonomous driving (level 3 and beyond) have been announced, notably in Henan, Jiangsu and Zhejiang provinces. But it is in Gansu (northwest of the country) that ambitious projects will soon take shape. Since this summer, a 13-km stretch of road in Lanzhou has been open to traffic, allowing autonomous driving to be tested with appropriate equipment. And there is a much more ambitious program. The first highway dedicated to autonomous freight transport will be built in 2025, over 400 km long. On the other hand, several countries such as Mexico, Canada, and the U.S. are deploying digital infrastructure to support communication between vehicles and networks to gather critical information, thereby reducing traffic congestion and improving road safety. Therefore, the rise in the development of smart cities is expected to drive the growth of the autonomous car market.

Additionally, China has filed nearly 3,803 international PCT applications, or about 16% of its total applications since 2010, meanwhile the US has filed nearly 4,343 PCT applications throughout the similar time frame, or approximately 52% of its entire applications. It shows that Chinese companies are filing much more patents in comparison to the US, but they are marginally extending their protection outside their own country.

Please note that the data for 2021 and 2022 are incomplete due to the 18-month publication delay of the patent literature.

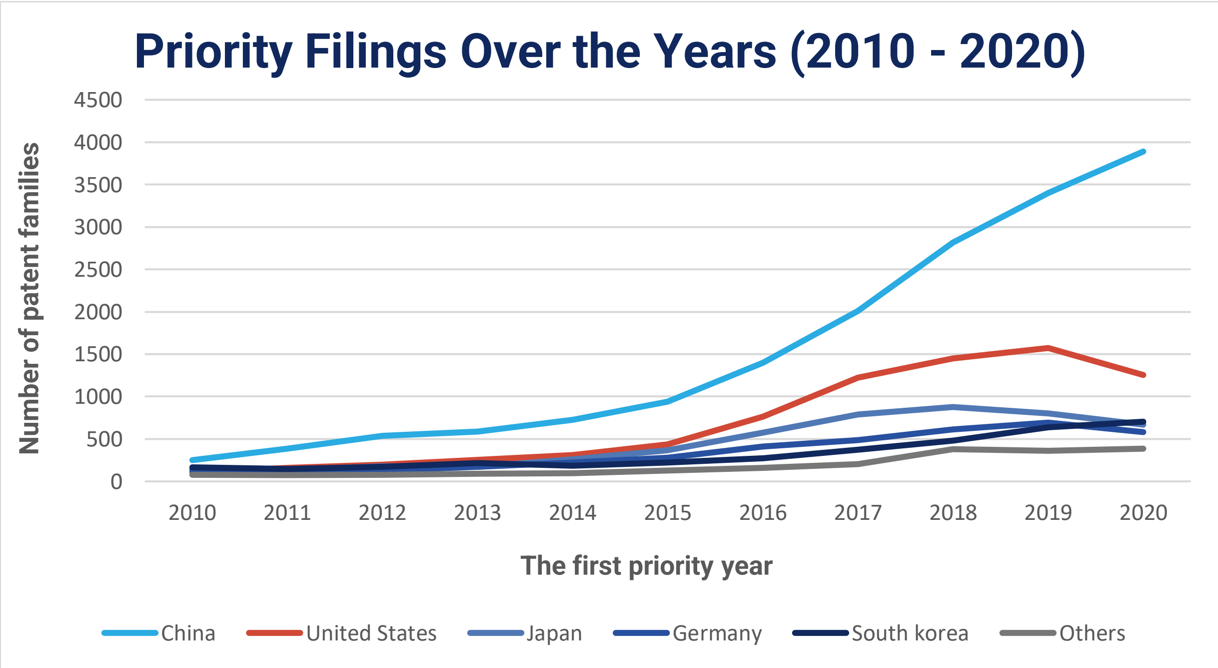

Figure 6 – AD Priority Filing over the years

[1] https://www.autonews.fr/hi-tech/la-chine-avance-sur-le-vehicule-autonome-111763

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The growth rate in the last years reveals high filing activity in Asia, with China's CAGR of 32%, Japan's CAGR of nearly 17% and South Korea's CAGR of 15.5% between 2010 and 2020. The United States shows a growth rate of 28.5% in the same time frame (2010 to 2020), ranking well behind China. In addition, Germany comes fourth with a CAGR of 16.5%.

Between 2010 and 2014, growth is on the rise for the vast majority of countries with an overall average of 20%. Over a 5-year period from 2015 to 2020, global patent filing activity has increased from 2439 to 7776. Thus, its compound annual growth rate stands at 26%.

According to GLOBE NEWSWIRE[1], in 2021, the global market size was $25.14 billion, with a compound annual growth rate of 25.7%, and was forecast to reach a value of approximately $196.97 billion by 2030. This is owing to the increase in the smart city development, which is a major factor driving the overall growth of the global autonomous car market, and thanks to the integration of cutting-edge technologies such as artificial intelligence and the Internet of Things in the transportation technology domain.

The market value forecast is reflected in the legal state of the patents in the field. About 82.2% of the patent families related to autonomous driving are alive, which is about 40,000 patents.

Patent landscape

Autonomous Driving

Market countries

China, the main market country

The number of documents published in the various national offices reflects the patent strategies of the actors in the sector, as the national filings are a good indicator of the markets that need to be protected. Please note that some players also target a protection in the geographical areas where the manufacturing sites of their competitors are located. The graph below is based on patent publication numbers in the different Offices.

[1] https://www.globenewswire.com/

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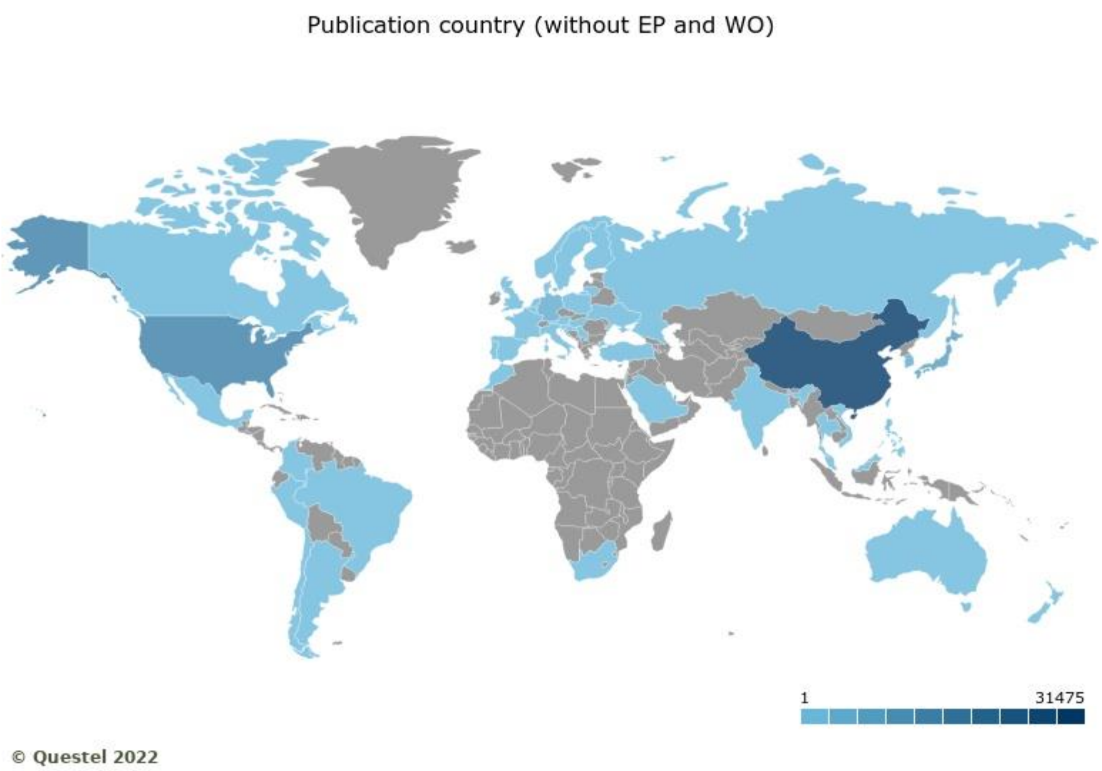

Figure 7 – AD Worldwide patent families by publication country

From the previous analysis, it is to be expected that China is going to offer a large size market for autonomous driving. 64% of the patent publications were published in China, which shows its position as the leading market. This status is further strengthened by the intensity of patent filings from China. The United States comes after with 28%, followed by 15% in Japan, and 12% in Germany.

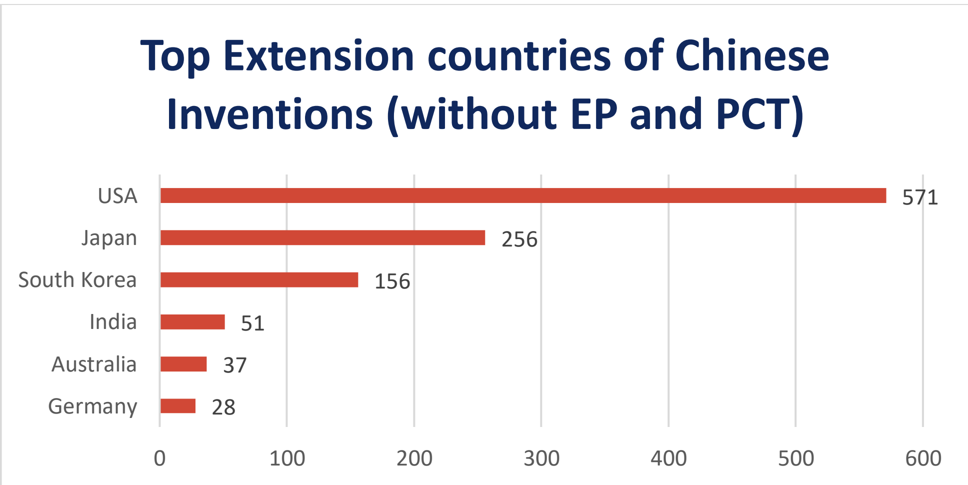

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Figure 8 – AD Patent publication countries of Chinese patents

As a matter of fact, most Chinese patent applications are published exclusively in China, and only 1.8% of Chinese applications are extended to the United States, which is the largest Western market for Chinese patents, followed by other territories, such as Japan with 0.8% and South Korea with 0.5%. Furthermore, 20% of US patents were extended in China, while 11% were published in Europe.

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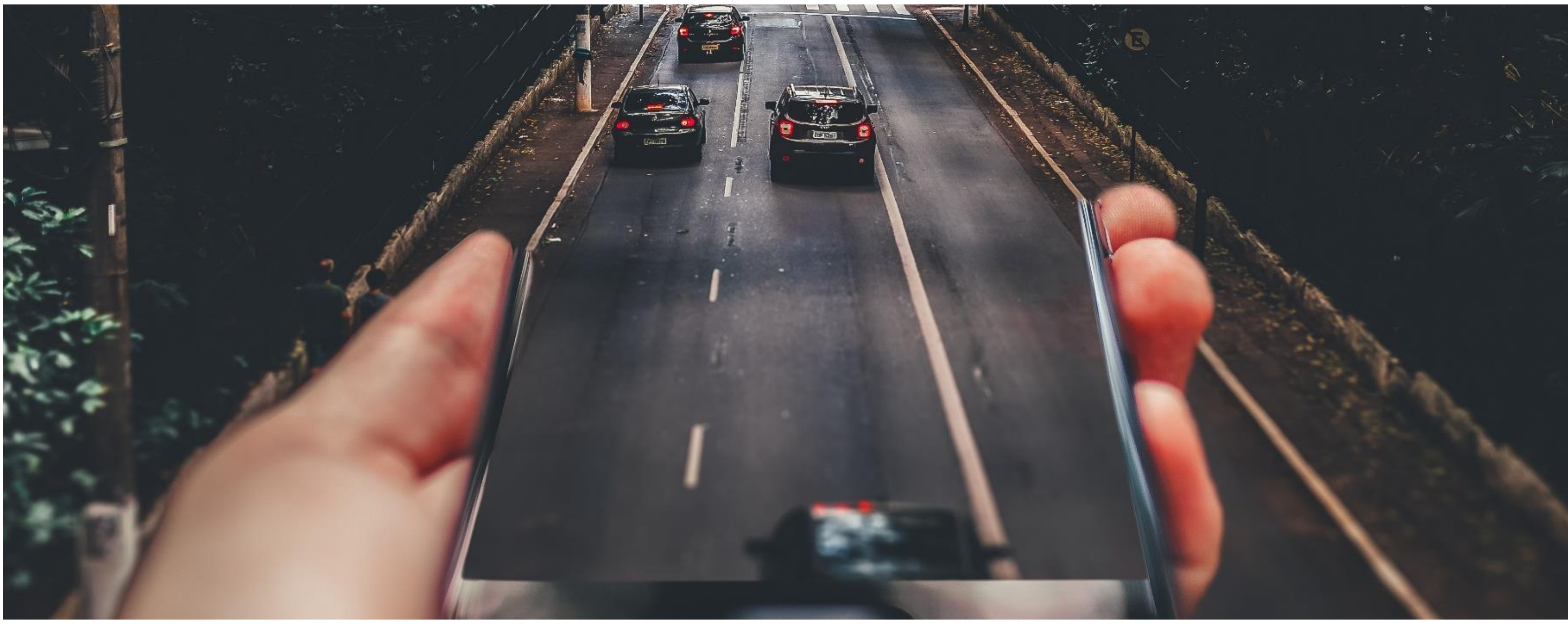
Patent landscape

Autonomous Driving

Players



China, USA, Japan, and Germany unsurprising domination

According to the European Patent Office (EPO) study on autonomous driving technology ("Patents and self-driving vehicles, the inventions behind automated driving", November 2018)[1], the major patent filings players related to autonomous driving are hundreds of different applicants operating in a wide variety of industries. The top 500 applicants accounted for 80% of all autonomous driving applications at the EPO during 2011-2017.

The EPO Patent Landscape (published in 2018) indicated that the top patent players are primarily:

- Automotive companies,
- Transportation, Machinery and Electrical Equipment firms,
- Information and Communication Technology companies,
- And Telecommunications companies.

Companies active in the automotive, other transport or related machinery and electrical equipment sectors filed half of these patent applications, while

[1] https://www.lemoci.com/wp-content/uploads/2018/11/OEB-EPO-Self-driving-vehicles-study.pdf

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companies specializing in information and communication technologies (ICT for automotive) and telecommunications companies share the other half.

The same study found that the autonomous driving will also disrupt many established industries and spawn new ones. The race is on with new entrants that have no track record in vehicle design, but a head starts in sensor software, AI, and communication. Automotive companies have entered the race with huge research and innovation capabilities and a long history of established automotive technologies.

On another study, between 1998 and 2016, realized by the WIPO[1] (published in November 2019) shows that sectoral breakdown of autonomous driving patenting over time supports the idea that the rise of AI, robotics, and mobility services is the main driver of the technology shift.

In the years immediately following 2005, nearly half of the patents appear to come from the technology sector. However, the traditional automotive sector then took over. Not surprisingly, the majority of patent applicants are owned by private companies, about 20% are individuals, and only 10% are universities or other public entities.

Google, Qualcomm, Mobileye, Uber, Baidu are not among the usual suspects in the automotive industry, but as early as the mid-2010s, they appear in the top 50 autonomous driving patent applicants. These top 50 applicants, led by names like Ford, Toyota, and Bosch, generated about half of the total patents. Non-automotive players also appear in the list of top patent players. Google and its self-driving vehicle subsidiary Waymo occupy the top ten spots, with more than 150 patents, ahead of automakers like Nissan, BMW, and Hyundai. They are followed by other companies like Uber and Delphi, which each hold about 60 patents and tie for 30th place.

[1] https://www.wipo.int/publications/en/details.jsp?id=4474

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TOP 50 APLLICANTS LIST			
Assignees	**Number of inventions**	**Country**	**Player Typography**
BAIDU	1193	China	Internet and technology
TOYOTA MOTOR	1066	Japan	Automotive manufacturer
ROBERT BOSCH	923	Germany	Automotive supplier
HONDA MOTOR	722	Japan	Automotive manufacturer
FORD GLOBAL TECHNOLOGIES	700	USA	Automotive manufacturer
BMW - BAYERISCHE MOTOREN WERKE	621	Germany	Automotive manufacturer
DAIMLER	585	Germany	Automotive manufacturer
HYUNDAI MOTOR	567	South Korea	Automotive manufacturer
GM GLOBAL TECHNOLOGY OPERATIONS	528	USA	Automotive manufacturer
LG ELECTRONICS	453	South Korea	Electronics company
DENSO	444	Japan	Automotive supplier
VOLKSWAGEN	411	Germany	Automotive manufacturer
WAYMO	402	USA	Automotive manufacturer
KIA MOTORS	398	South Korea	Automotive manufacturer
AUDI	358	Germany	Automotive manufacturer
HERE GLOBAL	340	USA	Automotive map solution and location service
HUAWEI	335	China	Telecommunication
NISSAN MOTOR	309	Japan	Automotive manufacturer
CHONGQING CHANGAN AUTOMOBILE	305	China	Automotive manufacturer
ZHEJIANG GEELY HOLDING GROUP	301	China	Automotive manufacturer
CHINA FIRST AUTOMOBILE WORKS (FAW)	300	China	Automotive manufacturer
ZF FRIEDRICHSHAFEN	269	Germany	Automotive supplier
UATC	255	USA	Software services
ZOOX	248	USA	Automotive manufacturer
HYUNDAI MOBIS	233	South Korea	Automotive manufacturer
MITSUBISHI ELECTRIC	220	Japan	Automotive supplier
SUBARU	216	Japan	Automotive manufacturer
TSINGHUA UNIVERSITY	191	China	Academic
PANASONIC INTELLECTUAL PROPERTY MANAGEMENT	161	Japan	Electronics company
PSA AUTOMOBILES	161	France	Automotive manufacturer
JILIN UNIVERSITY	159	China	Academic
INTEL	154	USA	Chip manufacturer
GM CRUISE HOLDINGS	143	USA	Automotive manufacturer
RENAULT	143	France	Automotive manufacturer
SAMSUNG ELECTRONICS	139	South Korea	Electronics company
HITACHI ASTEMO	138	Japan	Automotive supplier
MOTIONAL	138	USA	Automotive manufacturer
WUHAN KOTEI BIG DATA	137	China	Software services
TENCENT TECHNOLOGY SHENZHEN	135	China	Conglomerate
CONTINENTAL AUTOMOTIVE	130	Germany	Automotive parts manufacturer
MAZDA MOTOR	130	Japan	Automotive manufacturer
IBM	129	USA	Computer hardware, software and services
QUALCOMM	128	USA	Telecommunication, Chip manufacturer
VALEO SCHALTER & SENSOREN	119	France	Automotive supplier
APTIV TECHNOLOGIES	114	USA	Automotive technology supplier
CHONGQING UNIVERSITY	114	China	Academic
GUANGZHOU WERIDE TECHNOLOGY	114	China	Automotive supplier
TONGJI UNIVERSITY	114	China	Academic
ZHIDAO NETWORK TECHNOLOGY BEIJING	112	China	Academic
JIANGSU UNIVERSITY	106	China	Academic

Table 1 – Top 50 Applicants of AD-Related Patents

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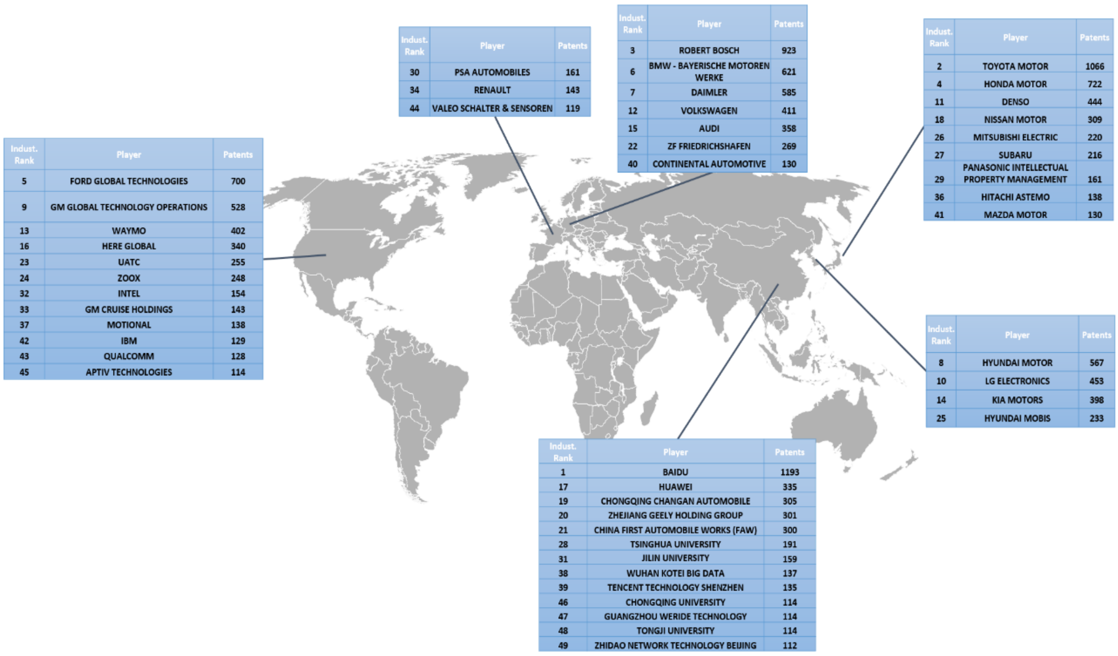
Trends in the industrial sector



Indust. Rank	Player	Patents
5	FORD GLOBAL TECHNOLOGIES	700
9	GM GLOBAL TECHNOLOGY OPERATIONS	528
13	WAYMO	402
16	HERE GLOBAL	340
23	UATC	255
24	ZOOX	248
32	INTEL	154
33	GM CRUISE HOLDINGS	143
37	MOTIONAL	138
42	IBM	129
43	QUALCOMM	128
45	APTIV TECHNOLOGIES	114

Indust. Rank	Player	Patents
30	PSA AUTOMOBILES	161
34	RENAULT	143
44	VALEO SCHALTER & SENSOREN	119

Indust. Rank	Player	Patents
3	ROBERT BOSCH	923
6	BMW - BAYERISCHE MOTOREN WERKE	621
7	DAIMLER	585
12	VOLKSWAGEN	411
15	AUDI	358
22	ZF FRIEDRICHSHAFEN	269
40	CONTINENTAL AUTOMOTIVE	130

Indust. Rank	Player	Patents
2	TOYOTA MOTOR	1066
4	HONDA MOTOR	722
11	DENSO	444
18	NISSAN MOTOR	309
26	MITSUBISHI ELECTRIC	220
27	SUBARU	216
29	PANASONIC INTELLECTUAL PROPERTY MANAGEMENT	161
36	HITACHI ASTEMO	138
41	MAZDA MOTOR	130

Indust. Rank	Player	Patents
8	HYUNDAI MOTOR	567
10	LG ELECTRONICS	453
14	KIA MOTORS	398
25	HYUNDAI MOBIS	233

Indust. Rank	Player	Patents
1	BAIDU	1193
17	HUAWEI	335
19	CHONGQING CHANGAN AUTOMOBILE	305
20	ZHEJIANG GEELY HOLDING GROUP	301
21	CHINA FIRST AUTOMOBILE WORKS (FAW)	300
28	TSINGHUA UNIVERSITY	191
31	JILIN UNIVERSITY	159
38	WUHAN KOTEI BIG DATA	137
39	TENCENT TECHNOLOGY SHENZHEN	135
46	CHONGQING UNIVERSITY	114
47	GUANGZHOU WERIDE TECHNOLOGY	114
48	TONGJI UNIVERSITY	114
49	ZHIDAO NETWORK TECHNOLOGY BEIJING	112

Figure 9 – AD Top 50 players word distribution

According to this study, among the top 50 players, we have been able to detect a significant presence of Chinese players (5 academics, 4 information and communication technology companies, 3 car manufacturers, 1 car equipment manufacturer). These players contribute with 3510 patents, or 7.2% of all patents. The competition is tight in the top 50 between Chinese, Japanese, German and American companies. In fact, the Japanese come second with a rate of 6.9% thanks to the contribution of car manufacturers (Toyota, Honda, Nissan, Subaru Mazda), followed by the Germans and Americans with a rate of 6.7% for each. The American progress in this field is due to various patented players, which are mainly car manufacturers (Ford, GMC), companies specializing in autonomous driving (Waymo, ZOOX, Motional), automotive suppliers (APTIV TECHNOLOGIES) and other software, telecommunications, and information technologies (HERE GLOBAL, INTEL, IBM QUALCOMM and UATC). On the other hand, German car manufacturers (BMW, DAIMLER, VOLKSWAGEN, and AUDI), automotive suppliers and parts manufacturers (ROBERT BOSCH, ZF FRIEDRICHSHAFEN, CONTINENTAL AUTOMOTIVE) come with a large number of patents (3,297 patents) in the top 50.

A total of 15% of patents are owned by the top 10 players. The most prolific is Baidu. The Internet giant, which develops maps for navigation, is also developing artificial intelligence for providing autonomous driving solutions. Most importantly, it has set up the Apollo platform for autonomous driving, on which many partners are collaborating. The Chinese Internet giant claims to have driven

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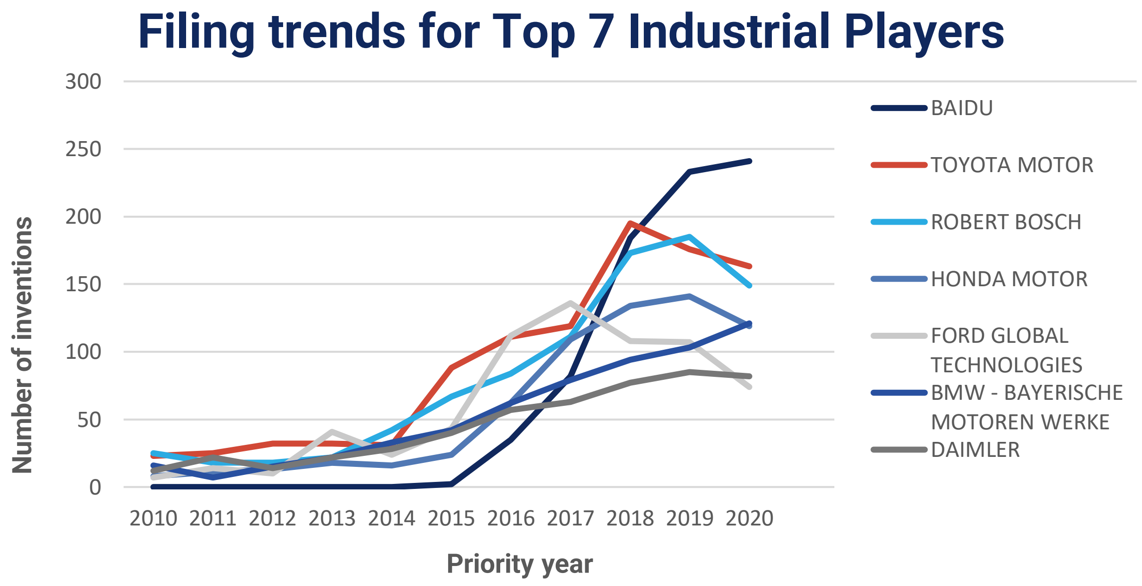
32 million kilometers[1] (compared to more than 20 million for Waymo in the U.S. on the road), in 1,000 vehicles.

The leaders are BAIDU with nearly 2.5% of the world patent filing ratio, equivalent to 1193 patents, followed by the Japanese automobile manufacturer, Toyota with thousands of patents, representing 2% of all patents in this field. Next comes ROBERT BOSCH with 1.8%. HONDA is ranked fourth with 722 patents related to autonomous driving (~1.4% of total patents). Automotive companies from Germany such as BMW - BAYERISCHE MOTOREN WERKE and DAIMLER contribute with 1.4% and 1.2% respectively. Coming behind is the South Korean automotive company HYUNDAI MOTOR with 567 patents, contributing 1.1% of the global autonomous driving-related patents rate.



Remark: Some companies ask early publication of their patents in order to rapidly fill the prior art space and block their competitors' future patents. This explains the high number of patents filed in 2020 for some players.The decrease observed for other players in 2020 may be more related to the traditional 18 months delay before publication.

Figure 10 – AD Filing Dynamics – Top 7 players

All top 7 companies have followed approximately the same rapid increase of patent filings from 2010 until 2020, however, BAIDU's filing trend is quite remarkable as it has staringly raised starting 2015.
Baidu is one of the largest AI and internet companies in the world, known for their highly popular search engine. Over 70% of Chinese search inquiries are performed through Baidu's search engine. The Chinese Internet giant has secured permits to offer a fully driverless commercial robotaxi service, with no human driver present, in Chongqing and Wuhan via the company's autonomous ride-hailing unit, Apollo

[1] https://www.autofutures.tv/topics/baidu-granted-china-s-first-ever-permits-for-commercial-fully-driverless-ride-hailing-services/s/8965b372-02c5-442d-b9bb-8dfc69195f45

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Go. According to Reuter[1], in 2017 China's Baidu launches $1.5 billion autonomous driving fund to accelerate its technical development and compete with its American rivals which is the reason for this important growth in the number of annual patent applications since 2015.

Baidu's dominance of the autonomous driving patent landscape, nevertheless, should not overshadow the existing business importance of Japanese, American and German automobile manufacturers in this field. Toyota, which is the second largest player, invested 300 billion yen ($2.8 billion) in 2018 in a new Tokyo-based company (The Toyota Research Institute-Advanced Development (TRI-AD)) that will build software for self-driving cars, according to a Wall Street Journal report[2]. Separately, Google[3] and Waymo, its subsidiary, announced a $2.5 billion funding round in 2021, which will be used to advance its autonomous driving technology and develop its team. Also, since 2017, in Germany the Federal Ministry of Digital Affairs and Transport[4] is working intensively on laws to facilitate autonomous driving aimed at making it possible to deploy vehicles with autonomous driving capabilities in regular operations by 2022. So, there will certainly be expected growth in this technology field, in the next few years.

Patents portfolio’s strength and impact

Patent citations, technological diversity, technical domain, patent remaining life, degree of novelty, and market coverage are all some indicators that can be used as a measure of firms’ technological capabilities and performance.

Using those indicators, comparison between competitors in terms of technological impact and portfolio value is possible.

Referring to metrics in the following graph (*Figure 11 - Autonomous Driving Player's Impact*) it can be deducted that:

- Baidu owns a strong portfolio value among identified competitors in the field of autonomous driving systems, closely followed by Toyota. Ford, Honda and Robert Bosch follow with lesser indicator’s value.
- Ford is a trendsetter in terms of technological impact and is trailed by Baidu.
- Baidu, Toyota, Robert Bosch, Honda, and Ford, all these players seem to cover a wide range of breakthrough technologies in their innovation

[1] https://www.reuters.com/article/us-china-baidu-autonomous-idUSKCN1BW0QJ
[2] https://futurism.com/toyota-self-driving-car-company
[3] https://www.cnbc.com/2021/06/16/alphabets-waymo-raises-2point5-billion-in-new-investment-round.html
[4] https://www.bmdv.bund.de/SharedDocs/EN/Articles/DG/act-on-autonomous-driving.html

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strategies when it comes to the broad spreading of cited IPC/CPC subclasses in their patent portfolio.

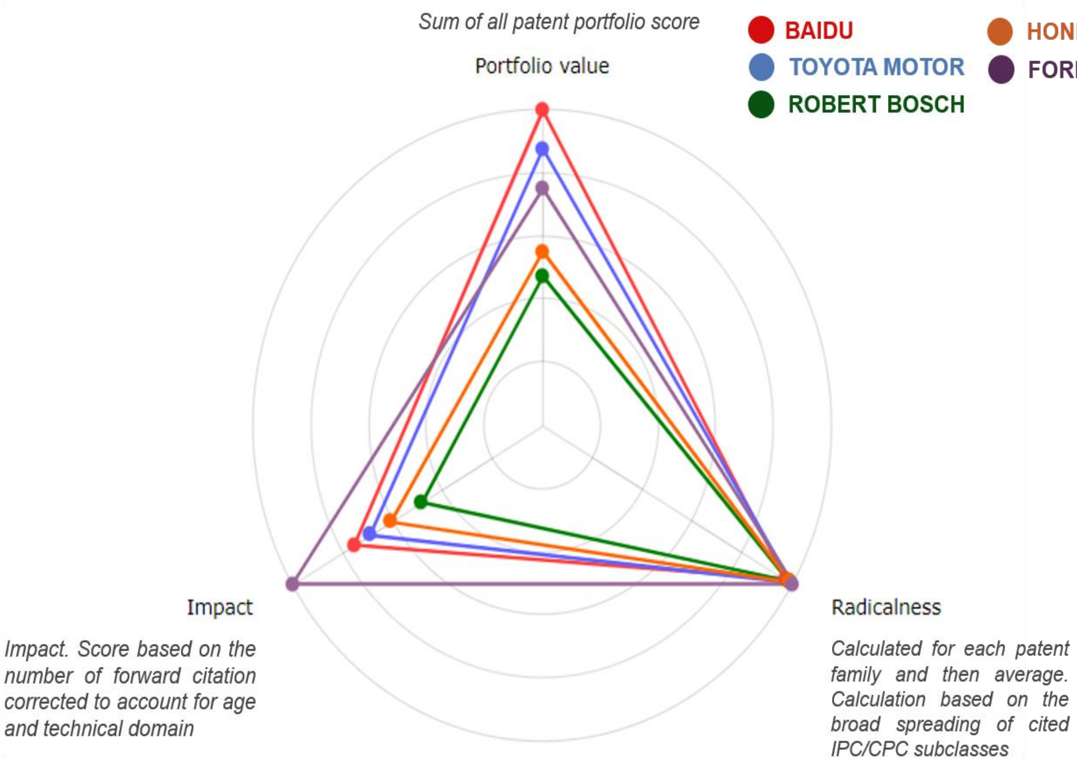

Figure 11 – Autonomous Driving Player's Impact

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Analyzing more closely the patents portfolios of some top actors, the technical influence of player's innovation activities and its importance in the technical domain can be spotted. The table below (*Table 2 - Autonomous Driving Impactful patents per actor*), displays in detail this impact, where:

- **Impactful patent** is the count of patent families with at least one non-self forward citation.
- **Interfering patents** is the count of patent families cited by an examinator for questioning the patentability or inventive of a patent application
- **Forward X** is the count of patent families cited by an examinator as category "X"
- **Forward Y** is the count of patent families cited by an examinator as category "Y"

	Impactful patent	Interfering patents	Forward X	Forward Y
BAIDU	741	389	219	314
TOYOTA MOTOR	668	315	185	269
ROBERT BOSCH	502	196	128	139
HONDA MOTOR	423	191	101	165
FORD GLOBAL TECHNOLOGIES	561	265	173	212
BMW	314	128	90	84
DAIMLER	297	96	66	73
HYUNDAI MOTOR	334	104	60	80
GM GLOBAL TECHNOLOGY OPERATIONS	426	189	128	146
LG ELECTRONICS	258	86	49	70
DENSO	284	163	105	141
VOLKSWAGEN	204	82	59	63
WAYMO	295	149	107	128
AUDI	232	104	79	71
HERE GLOBAL	276	71	54	51
HUAWEI	187	83	53	57
NISSAN MOTOR	200	103	58	87
CHONGQING CHANGAN AUTOMOBILE	96	54	31	47
CHINA FIRST AUTOMOBILE WORKS (FAW)	117	61	36	49
ZHEJIANG GEELY HOLDING GROUP	212	160	85	145

Table 2 – Autonomous Driving Impactful patents per actor

The top position of Baidu followed by Toyota is not only marked by the number of patent families but by the impact and the value of their portfolios. Ford 5th position in terms of inventions number is faced with a stronger ranking in terms of portfolio technical impact.

An area of little aggression so far

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Only 17 infringement litigations were observed, in the US, Germany, China, and Italy. Out of almost 50,000 patent families, this number is incredibly low and represents a percentage of 0.03% of the total patents in this field. This very low level of patent litigation is correlated with the technology field's low maturity, indicating that numerous technologies are not yet commercialized, and also that market players are racing each other on technology performance and data volumes to win market share. The patent litigations could come later when the market growth decelerates.

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Patent landscape

Autonomous Driving

Segmentation analysis

High-precision map and positioning

6,314 patent families (~13% of the global database) involve high-precision map and positioning technologies.

High-precision maps has been fundamental to the autonomous driving industry as it improves the reliability, and consequently safety, of the system through high-precision positioning, over-the-horizon sensing, lane-level path planning, and other services provided by the high-precision map.

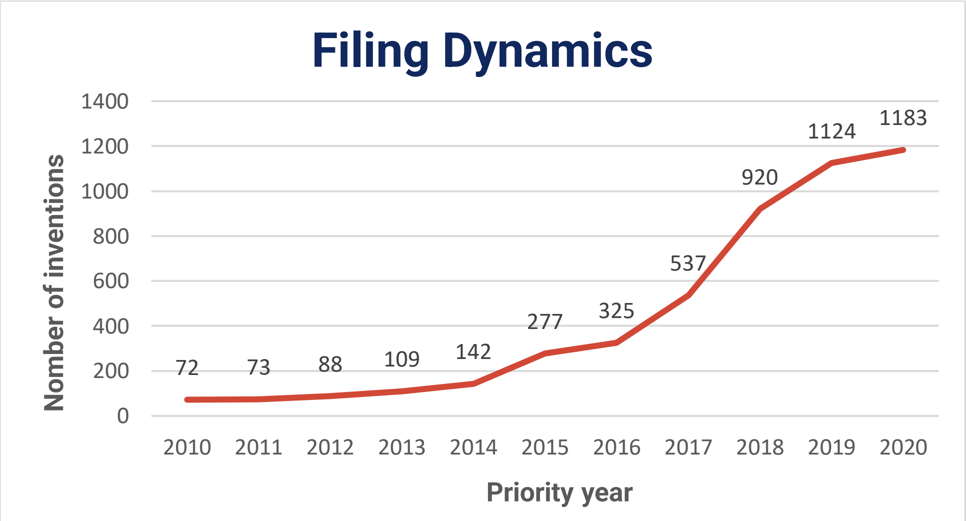

Figure 12 – High precision map patent filing dynamics

From 2010 to 2020, the filing dynamics exhibit a notable rise, from 72 to 1183. Its compound annual growth rate (CAGR) stands at 32.3%. China is the largest contributor to this technology, responsible for 55% of the inventions. Moreover, as it is the case with autonomous driving, Chinese players show a significant gap with US and German players, which come respectively second and third place among the ranking.

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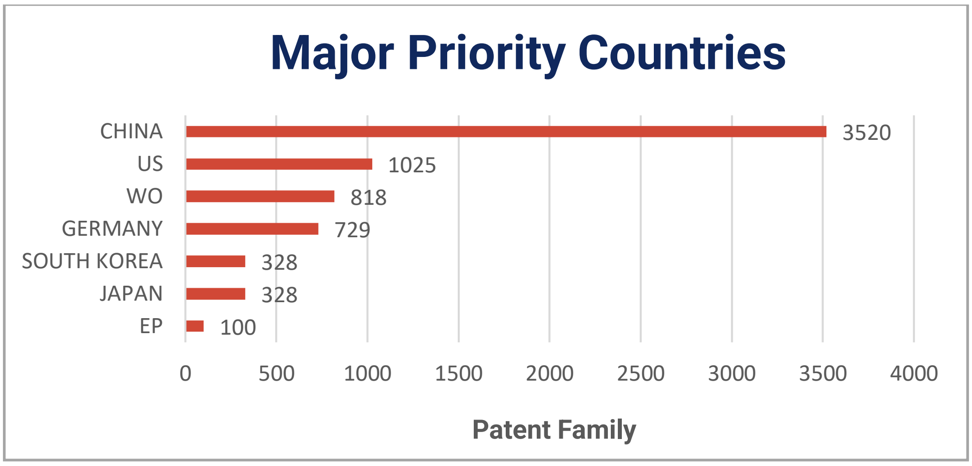

Figure 13 – High-precision map main R&D countries

According to CITIC Securities' forecast[1] in 2019, the future market potential of the high-precision map industry is huge in China. By 2030, the global high-precision map industry will exceed US$20 billion, and the potential market size in China will be about 30 billion yuan.

Therefore, it can be clearly noted that more and more Chinese automotive manufacturers and map developers have invested increasing resources in high-precision maps. For example, SAIC invested in CivilMaps[2], Alibaba acquired AutoNavi[3] Maps and invested heavily in high-precision maps, while Tencent took over NavInfo[4] and created an autonomous driving department within it. Baidu has taken autonomous driving and high-definition maps as the starting point for its AI strategy and, in late 2015, announced a five-year plan to put autonomous driving vehicles into mass production. Besides, the application of high-precision maps is not limited to autonomous driving, but also extends to areas such as smart cities, smart tourism, public safety, real estate, transportation, new retail, etc.

On the other hand, regarding non-Chinese companies, many OEMs have also collaborated with tech companies to get ahead of each other. For example, Germany's Audi, BMW, and Daimler are sharing their sensor data through cloud services provided by HERE Technologies[5]. In addition, GM and VW have chosen to rely more heavily on Mobileye's third-party services to get their maps ready to use. In addition, one of the big names in the industry, Google, dominates digital mapping technology and has already proposed the HD map solution. US-based technology services company[6] has also opted for partnerships with Avis, Lyft and the French-Italian-American multinational automotive group "Stellantis" to establish the HD map for the autonomous driving market growth.

[1] https://www.zhitongcaijing.com/content/detail/225071.html
[2] https://www.greencarcongress.com/2018/05/20180513-civilmaps.html
[3] https://www.reuters.com/article/us-autonavi-deals-alibaba-group-idUSBREA3A15620140411
[4] https://www.reuters.com/article/us-china-tencent-hldg-navinfo-idUSBREA4501520140506
[5] https://www.businessinsider.com/bmw-mercedes-audi-here-map-data-2016-9
[6] https://www.fortunebusinessinsights.com/hd-map-for-autonomous-vehicles-market-105931

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Now as per the diagram below, regarding the key players for patent filings in this technology area, Baidu appears to be the leading player, with 318 patents (5% of the high-precision map database), followed by HERE Global, a provider of location planning and mapping software, with about 295 patents (4% of the high-precision map database). German multinational automotive supplier, Robert Bosch, came next with 213 patents in this technology field. In 2022, according to Green Car Congress Magazine[1], Bosch is strengthening its market position with the acquisition of Atlatec, which is a German high-resolution digital maps supplier for driver assistance and automated driving.

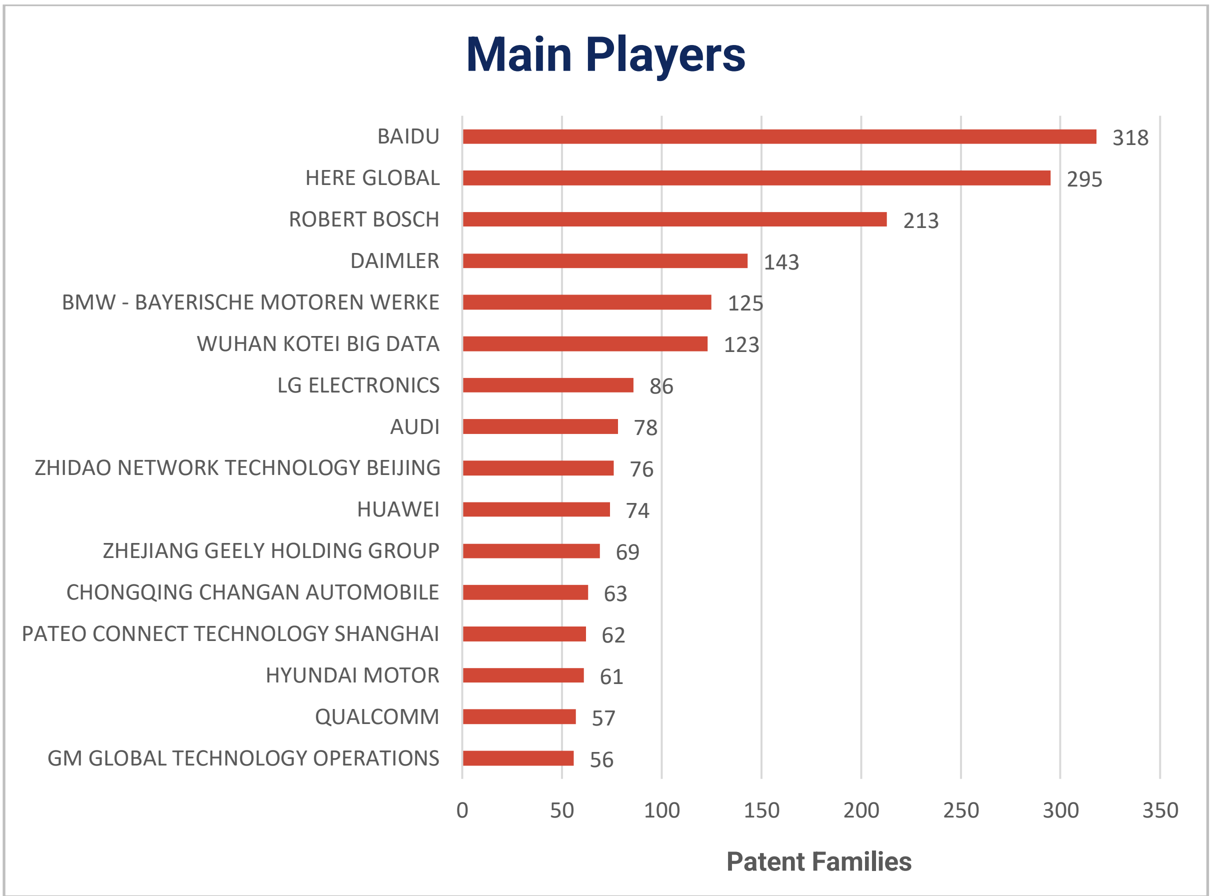

Figure 14 – High-precision map top players

Perception

32,598 patent families (66% of the global database) concern perception technologies.

[1] https://www.greencarcongress.com/2022/02/20220228-bosch.html

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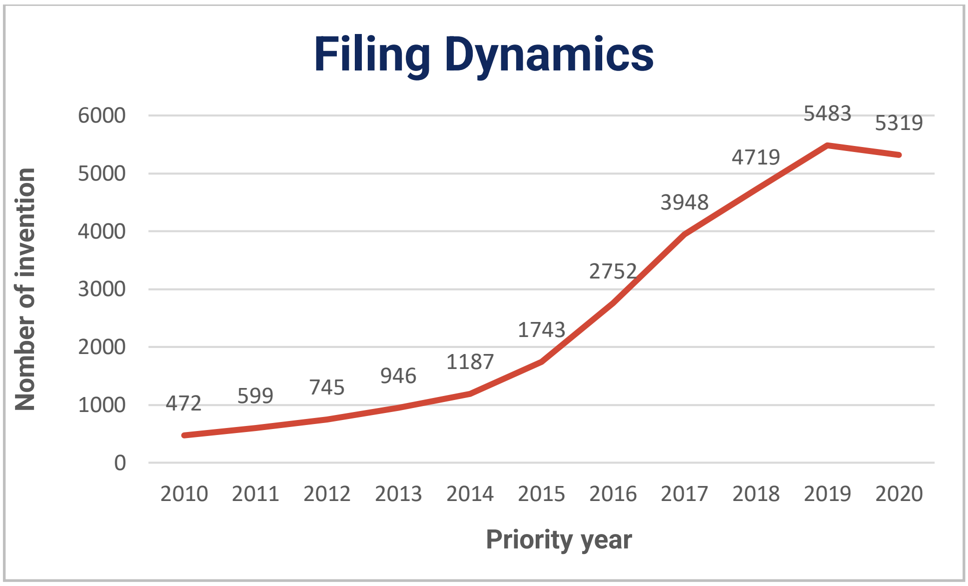

Figure 15 – Perception patent filing dynamics

Sensing technology is an expanding technology and a pillar of this industry. As sources of information and key parts of the automotive electronic control system, automotive sensors are essential to the development of automotive intelligence and automated driving. Today, autonomous vehicle developers are using high-end, industrial-grade sensors (lidar, cameras, and radar) and massive centralized computing. The push toward autonomy requires more and more computing power as increasingly demanding algorithms process growing amounts of sensor data.

From 2010 to 2020, the filing dynamics exhibit a notable rise, from 472 to 5319, an annual growth rate (CAGR) of 27.4%. Such as the case of the high precision map technology, China is the biggest technology contributor, accounting for 41 % of inventions, with a large gap from the 2nd place, United States, holding only 15 %, and followed by Japan with 10 %. South Korea and Germany each hold 8% and comes 4th and 5th. Based on McKinsey & Company's survey[1] in January 2019, China has strong potential to become the world's leading market for autonomous driving. In this baseline projection, such vehicles may represent up to 66% of passenger miles traveled by 2040. In market share, autonomous vehicles will account for just over 40 % of new vehicle sales in 2040, and 12 % of the installed fleet.
As China becomes the world's largest automotive market and automobiles become increasingly electronic, integrated, and intelligent, automotive sensors have great commercial potential.

[1]https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/How%20China%20will%20help%20fuel%20the%20revolution%20in%20autonomous%20vehicles/How-China-will-help-fuel-the-revolution-in-autonomous-vehicles-vF.pdf

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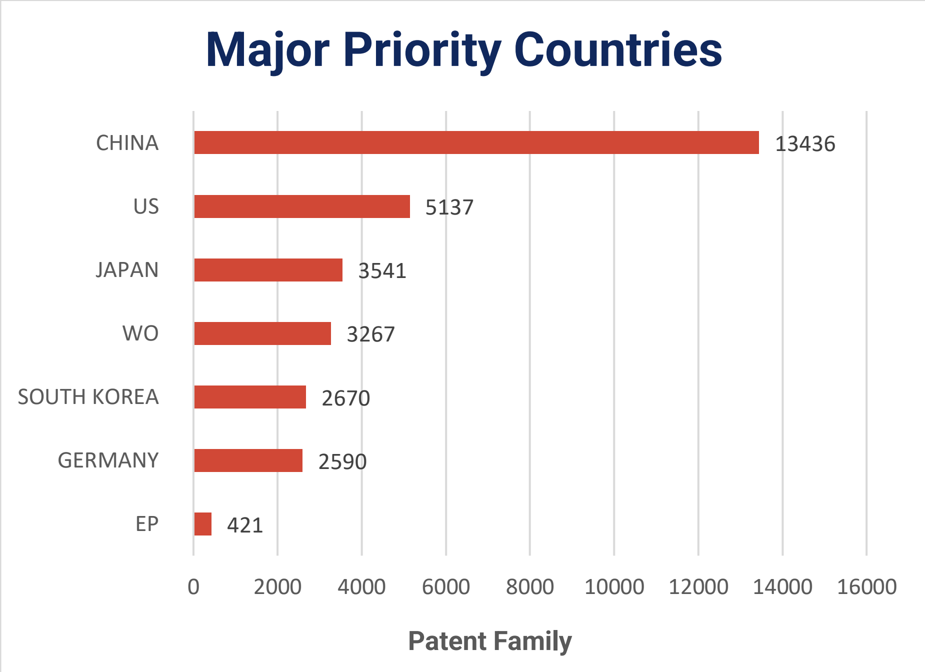

Figure 16 – Perception main R&D countries

Meanwhile, and according to the market research agency report Mordor intelligence[1], the United States automotive sensors market is expected to register a CAGR of 10% during the forecast period, 2020-2025.

[1] https://www.mordorintelligence.com/industry-reports/us-automotive-sensors-market-industry

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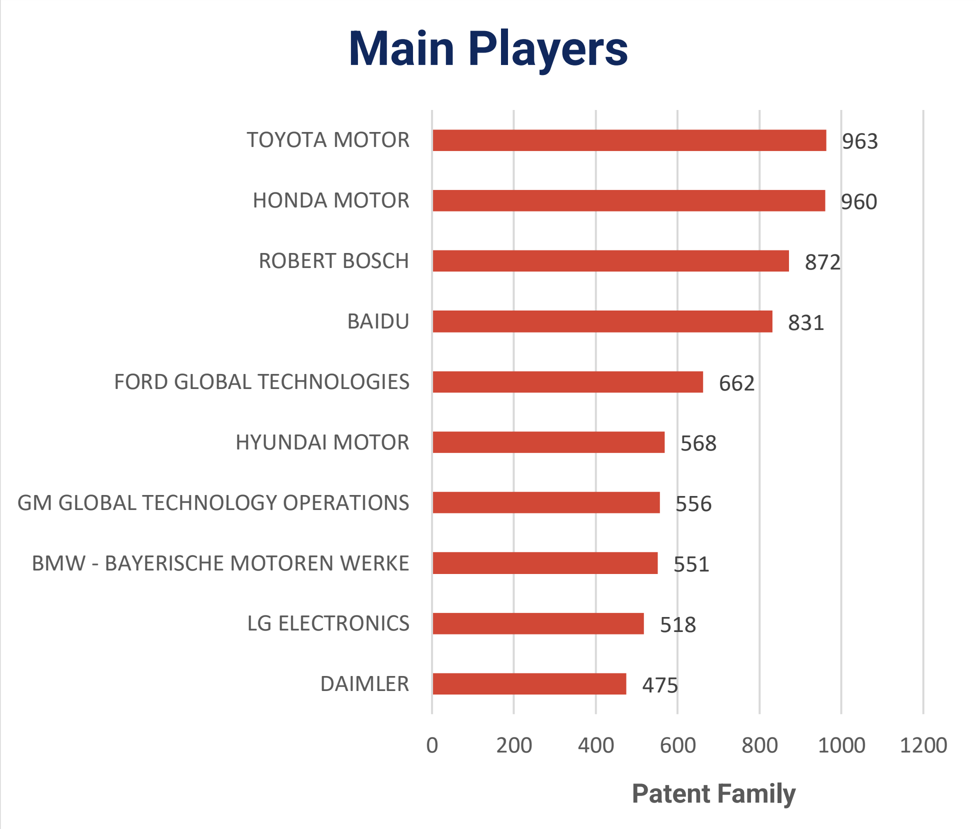

Figure 17 – Perception top players

Among the race towards the summit of the leading players, Toyota holds the highest patent portfolio with 963 patents in this field, closely followed by Honda with 960 patents. Robert Bosch comes third with a contribution of 872 patents and Baidu ranks fourth with 831 patents. It is worth noting that 21% patents of the global database are owned by the top ten players.

Since 2012, Toyota has expanded its patenting activity to protect not only the sensors but also their integration in a vehicle and their operation in a real environment. Toyota is in a better position in terms of IP in this domain, ensuring exploitation of its systems as well as potentially blocking other players. Accordingly, Toyota can control the different levels of the supply chain, from the sensor components to the final system. However, according to a recent report published by Reuters[1], Toyota's subsidiary Woven Plant unit is working to develop advanced self-driving vehicle technology without the use of pricey sensors, including lidars. The subsidiary told Reuters it can collect the data used to train its self-driving technology by using inexpensive cameras. The goal here is to develop the system quickly and successfully without exorbitant costs.

[1] https://www.reuters.com/article/us-toyota-woven-planet-autonomous-idUSKBN29Y1YF

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Planning, decision-making and control

29,269 patent families (60% of the global database) are related to planning, decision-making and control technologies.

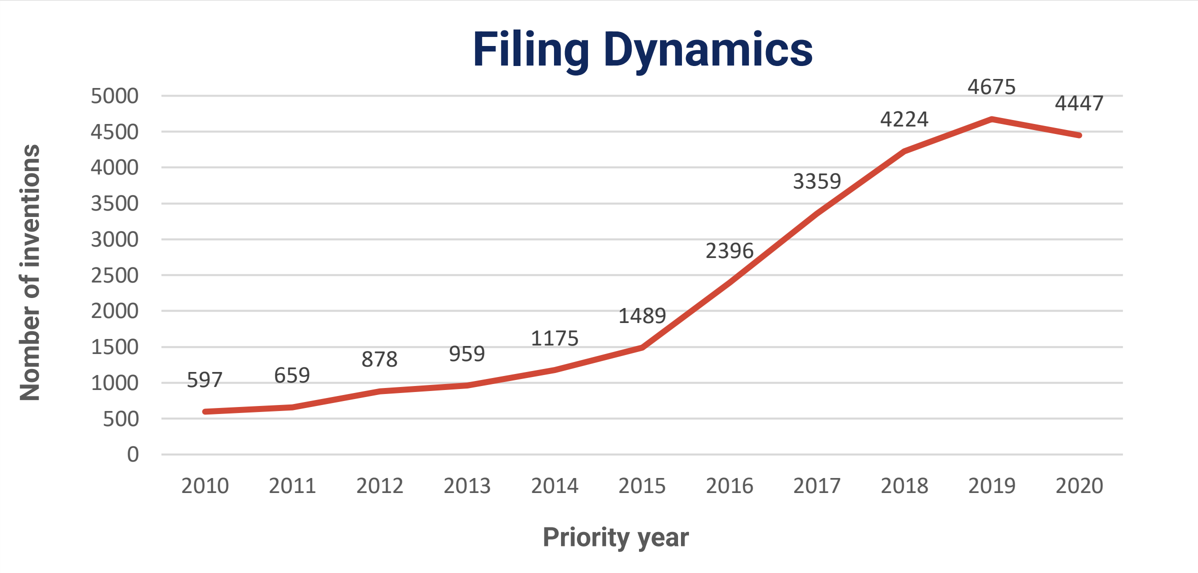

Figure 18 – Planning, decision-making and control patent filing dynamics

Software is playing an increasing role in vehicles, from managing electric motors and batteries to supporting functions such as autonomous driving, entertainment, and navigation. More specifically, autonomous driving is a comprehensive intelligent system which is highly dependent on the progress of software integrating path planning, decision-making and motion controlling technologies. Between 2010 and 2020, the dynamics of patent filings related to planning, decision-making and control technologies, has witnessed a growth from 597 to 4447 patents. Its compound annual growth rate (CAGR) has reached 22.24%.

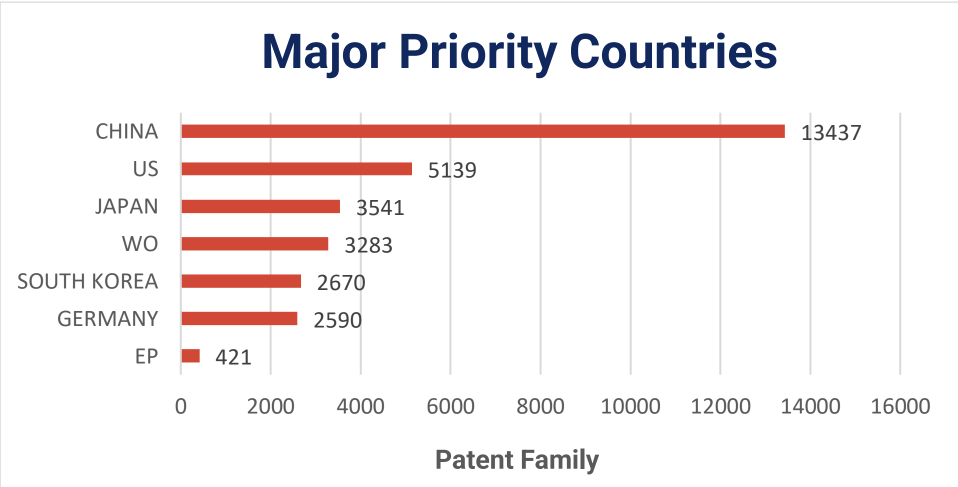

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Figure 19 – Planning, decision-making and control main R&D countries

Now when it comes to the expected market size, the global automotive artificial intelligence (AI) market is expected to reach approximately US$19.1 billion by 2030 and grow at a CAGR of 23.3% from 2022 to 2030, according to the global market research and consulting organization, Precedence Research [1]. The increasing trend towards the adoption of autonomous driving vehicles is one of the most important growth engines in this field. These vehicles are required to use such systems to enhance their reliability, efficiency, and performance.

For the same reasons as the previous two technology segments, this technological field is expanding in China with a contribution of 45% of the global patent count, far behind the United States, which holds only 17%. In third place comes Japan with 12%, followed by South Korea and Germany with 9% each. In related news, McKinsey & Co[2] estimated in 2019 that China's potential market for autonomous driving Taxies, Buses, Trucks and other equipment and software was worth trillions of dollars.

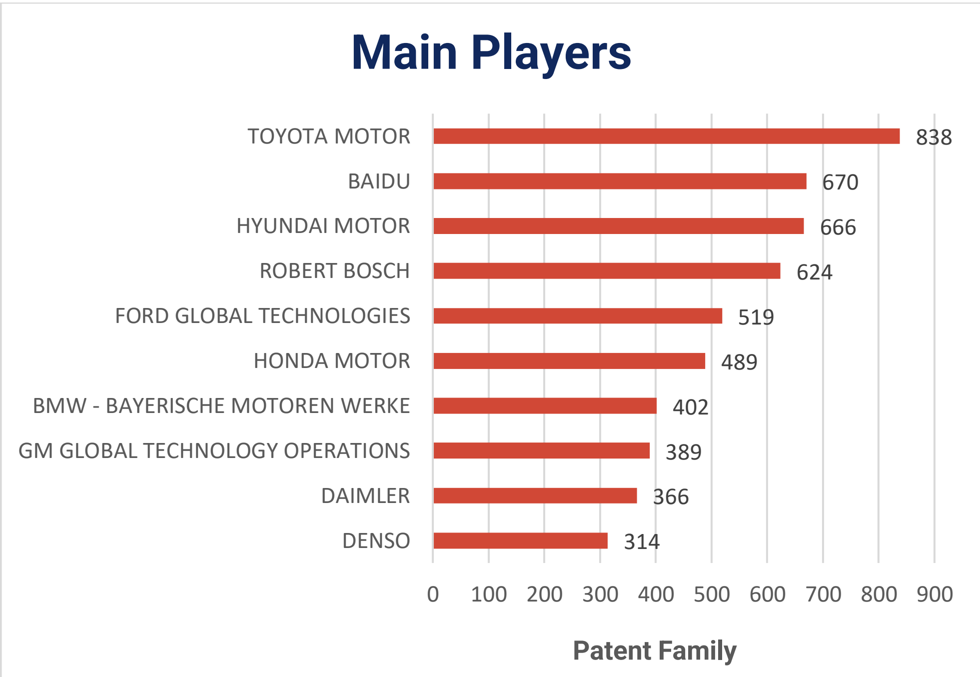

Figure 20 – Planning, decision-making and control top players

On the list of top patent filing players, Toyota leads the field providing 838 patents, followed by the Chinese giant Baidu with 670 patents, and then South Korea's Hyundai Motors with 666 patents. Robert Bosch comes in fourth with a

[1] https://www.precedenceresearch.com/automotive-artificial-intelligence-market
[2] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-china-will-help-fuel-the-revolution-in-autonomous-vehicles

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contribution of 624 patents and the American car manufacturer Ford with 519 patents. According to the Nikkei report[1] of January 2022, Toyota is planning to launch its own operating system, which would be capable of handling advanced operations such as autonomous driving, for its vehicles by 2025. Toyota's automotive software platform Arene will compete with German rivals, Volkswagen Group and Daimler, with VW working on its 'VW.OS' software and Daimler planning to roll out its own 'Mercedes-Benz Operating System' in its cars by 2024. Meanwhile, in 2021, reported in Forbes[2], Chinese internet search giant Baidu has initiated a multi-modal mobility-as-a-service pilot program. The program to incorporates numerous various self-driving vehicle platforms, all using the company's Apollo autonomous driving solution. Apollo vehicles are now being tested, although without public passengers, in 27 other Chinese cities. The company expects to introduce public robotaxis to all of those cities during the next two years.

[1] https://asia.nikkei.com/Business/Automobiles/Toyota-to-launch-own-operating-system-vying-with-Tesla-and-VW

[2] https://www.forbes.com/sites/davidsilver/2021/02/12/baidu-launches-self-driving-cars-shuttles-buses-vending-and-even-police-robots/?sh=6766318f28c7

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Autonomous Driving – Others

Connectivity and automation are different solutions that are often developed in tandem. These technologies may hold the key to eliminating driving errors and traffic jams, which means safer and healthier roads. Within this technology segment, our study shows some patents that are related to connectivity and data transmission inventions used in autonomous driving. Here, autonomous driving systems share information with other sources inside and outside the vehicle. This can be with other vehicles, with the road infrastructure, or with any other network or connected object.

This particular technological category includes 2,573 patent families (5% of the global database), mostly related to network and communication technologies. The Chinese domination is once again evident in this category, with a contribution that exceeds 50% of the global number of patents filed between 2010 and 2022. While during the same period of the analysis, the United States is in the second position with 23% followed by South Korea and Japan with 11% and 5% of overall patents, respectively.

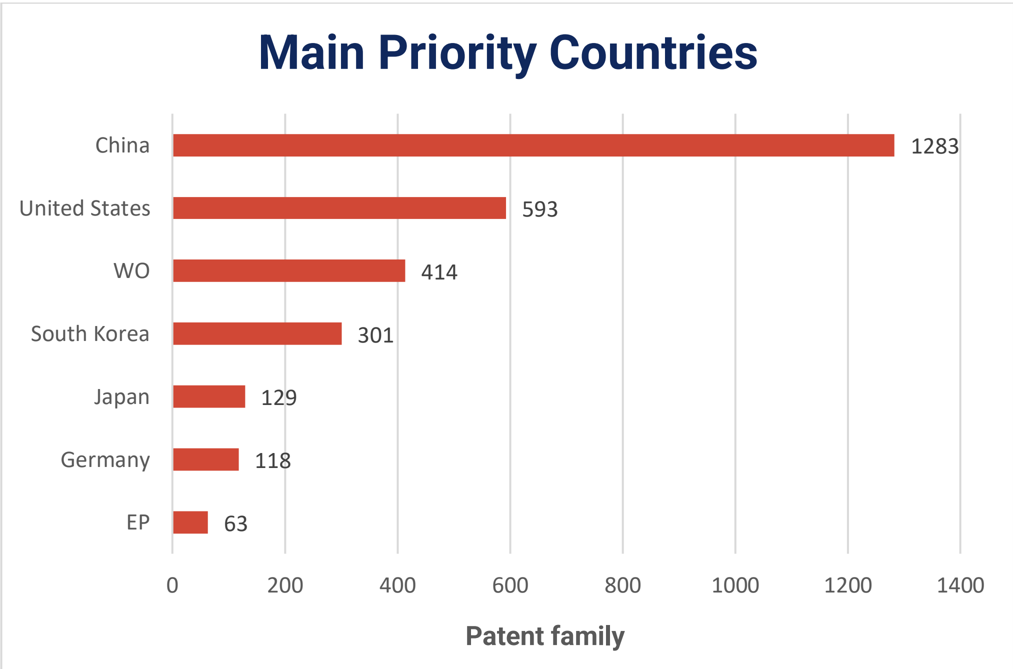

Figure 21 – AD others Main R&D Countries

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According to the chart below, LG Electronics is in the first place with nearly 200 patents, followed by Baidu with 90 patents, then Japan's Toyota automobile manufacturer with 41 patents, whereas Volkswagen and Huawei shared the fourth rank with 37 patents contribution each. Besides, 20% of the global patents are owned by top 10 players. Furthermore, it should be noted that, for this segment, there is a strong presence, in advanced positions, of the automotive manufacturers as well as the telecommunication companies. This fact may lead to future collaborative projects between them.

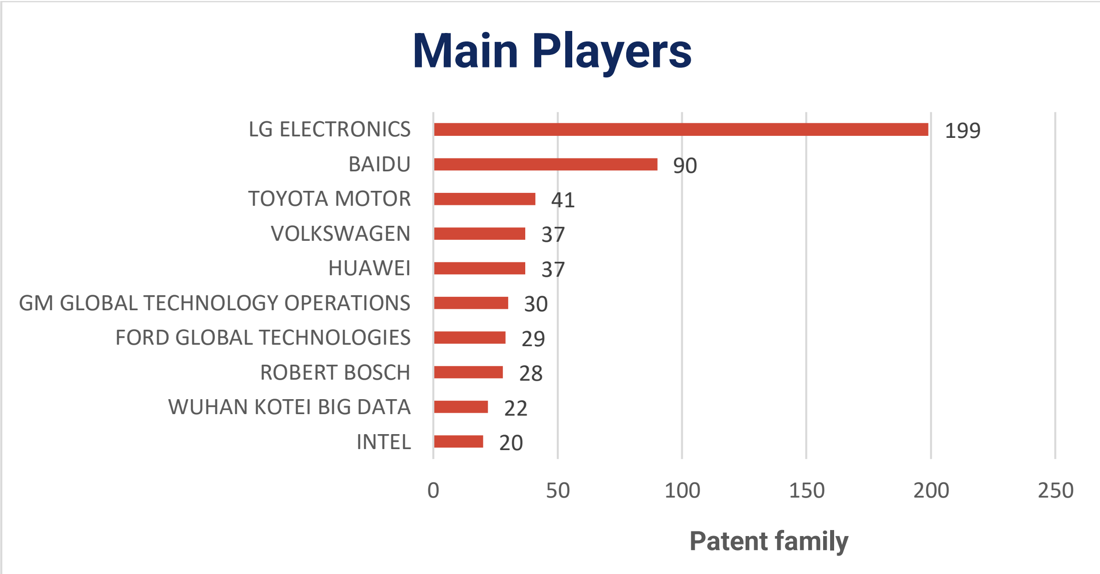

Figure 22 – AD others Patent filing top players

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Patent landscape

Smart Transportation

Filing trends

A high growth

This report analysis timeframe was limited to the period starting from 2010 till October 2022. 35 858 patent families of Smart Transportation related patent families were detected in this timespan.

The technology investment trend during the last years, namely from 2010 to 2020[1] can be depicted in the following graph clearly displaying the increase in patenting activities:

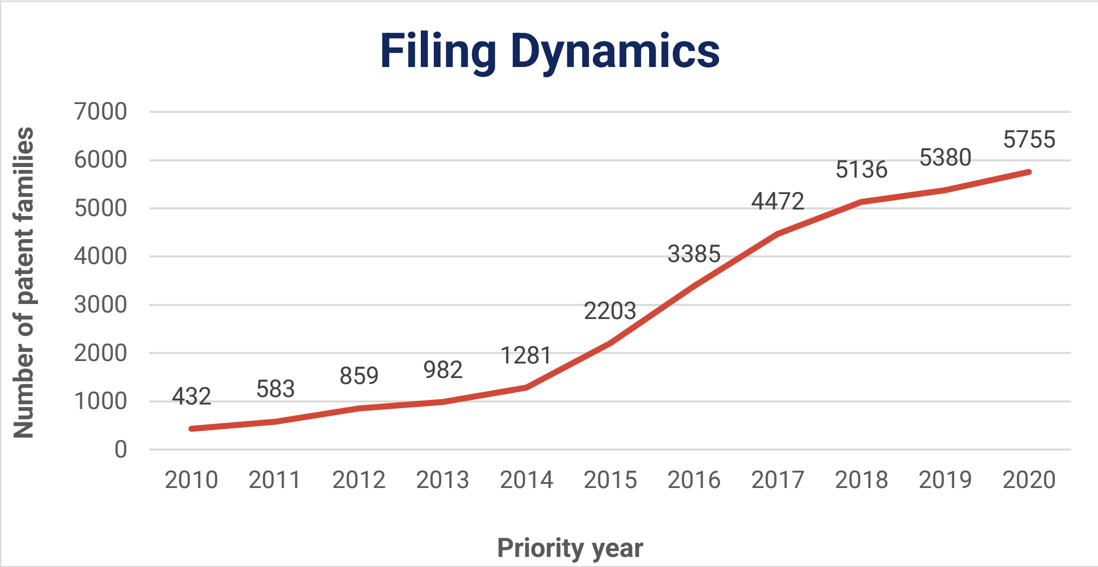

Figure 23 – ST Filing Dynamics

The high growth rate in the last years can reflect the impact of emerging technologies such as IoT and 5G communication on this field. The CAGR value recorded between 2014 and 2020 was 28%, a value that displays a strong position for Smart Transportation among other new generation technologies.

Patent landscape

[1] Due to the delay between the priority filing of a patent and its publication by patent offices, usually 18 months, the last complete year of information used in the current report is 2020.

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Smart Transportation

Inventions' origin

Asian dominance: The biggest patent filings number for China and the highest growth rate for South Korea

Priority country data may be used to indicate the main R&D locations, as most players file their first patent applications locally.

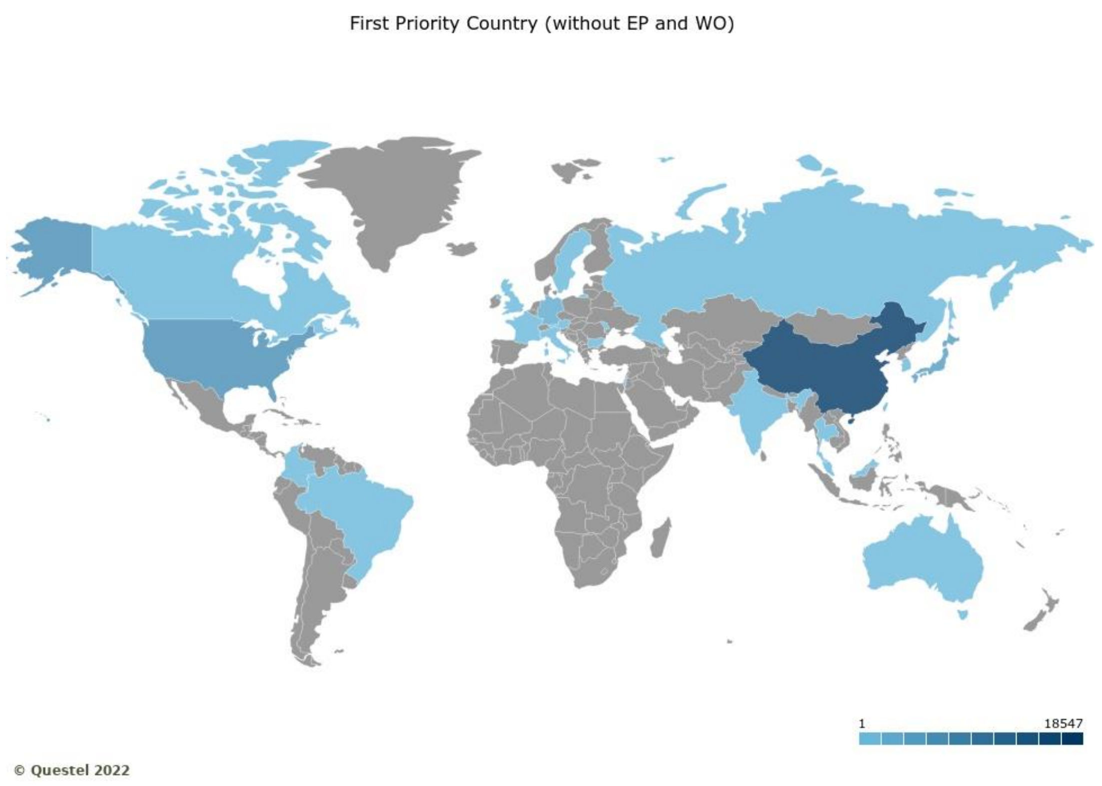

Figure 24 – ST Worldwide Patent Filing Countries

Analyzing the dynamics from 2010 to 2020, it was noticed that 46% of Smart Transportation related filing activities were in China. 19% of the global patent filing activity was attributed to the US followed by 14% for Japan. Europe highest contribution was associated to Germany with an 8% share, while South Korea came after with just 6%.

Since 2010, China is leading in terms of number of inventions with 13,952 patent families. The Chinese growth rate is keeping a steady pace with a CAGR of 31% from 2010 to 2020. According to the data[1] of Huajing Industry Research Institute, the number of autonomous driving-related industries in China has proliferated

[1] http://www.huaon.com/channel/other/692929.html

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since 2014 though the growth rate slowed slightly in 2020 due to the impact of the pandemic.

USA followed China with almost the same pace, 5,660 patent families and a CAGR of 30% for the same period. Nevertheless, a lower granted patent families / total patent applications ratio is observed in China compared to the USA; from 2010 to 2018[1], 42% of Chinese patent applications are granted whereas the rate is 78% for the American ones. This phenomenon could partially be explained by the number of revoked patents in those two countries as 13% were invalidated in China in comparison to the extremely low percentage of 0.3% in the US, which can point out to the American rigid quality demands. Applicants' abandonment rate is another factor that can be considered where the rate in China (24%) is three times higher than the USA (8%). The main contributors to those numbers were noticed to be the Chinese universities, as mainly both revoked and abandoned patents came from the academic.

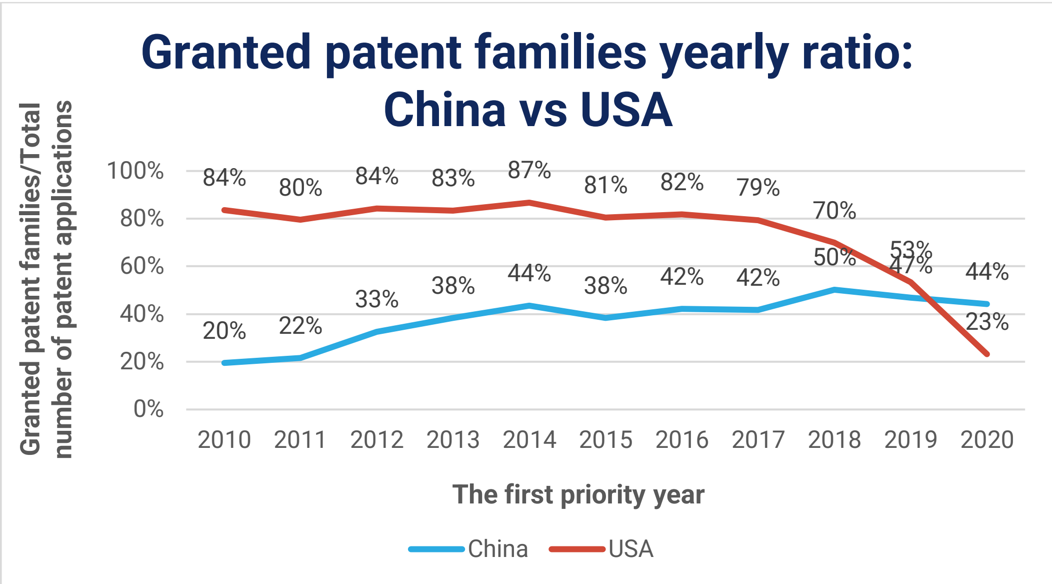

Figure 25 – ST Granted patent families ratio China vs USA comparison

Chinese patent applications average yearly contribution to the world patent filings accounted for around 49% for the period from 2010 to 2020, with 60% for 2012 (highest yearly contribution) and 38% for 2017 (lowest yearly contribution); whereas the US, the second major country, average yearly contribution accounted to just 18%. China high-rate contribution could be related to the smart transportation projects in the country. According to China Daily[2], China began promoting intelligent urban transportation during the 12th Five-Year Plan (2011-

[1] The comparison is limited to 2018 as the drop in ratio value observed in the graph starting 2019 could be misleading, as the patents may still be under examination
[2] https://global.chinadaily.com.cn/a/202205/21/WS62882a40a310fd2b29e5e1af.html

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15) period with 36 pilot cities completed in the Urban Public Transport Intelligent Application Demonstration Project. During the 13th Five-Year Plan (2016-20) period, the planning and construction of Internet Plus urban public transportation helped in integrating mobile internet and intelligent public transportation. Beijing, Shanghai, Hebei and Hunan provinces and other places have conducted pilot and demonstration projects in areas such as autonomous driving and vehicle-road coordination and unmanned buses in Suzhou, Shenzhen, Changsha and Xiamen have begun operations.

Moreover, there are almost 1,952 PCT applications from China, accounting for ~10% of its total applications [1] since 2010, whereas almost 1,345 PCT applications from USA at the same period, which is ~26% of its total applications.

Please note that the data in 2021 and 2022 are incomplete due to the 18 months of publication delay of patent literature. Nevertheless, some patents are included in the search results due to early publication policies, especially in China where there are ~18% utility models among the Chinese patent families.

The growth rate in the past few years shows a strong filing activity from Asia, with a CAGR of 39% for South Korea, 24% in China and a 16% for Japan from 2015 to 2020. The American 44% growth rate in the beginning of the last decade (2010 to 2015) dropped to 17% between 2015 and 2020, a tendency noticed for most major countries, as for China for example who passed from 38% to 24%. A more extreme decline can be seen for Germany where the 61% CAGR very high value (2010 to 2015) dropped to just 9% (2015 to 2020). This clearly illustrates the inventions dynamics for Smart transportation that seem to have exited the Peak of Inflated Expectations. The only exception for this pattern is South Korea where it seems that growth rate kept increasing, from 23% to 39% for the same previous periods of time. This could be explained by the ambitious South Korean Smart City Evolution project and initiatives in which Smart Transportation is one of several key technologies' fields. According to Forbes[2], Korea's National Strategic Smart Cities Program is an initiative that is emerging as the most successful smart city program in the world, promising to serve 70 cities by 2030, to cover 60% of Korea's population by 2040, and to drive a whole new generation of Korean exports.

In terms of legal state, around 81% of Smart Transportation related patent families are alive[3].

[1] Applications stands for first application to be in the mentioned country for the family

[2] https://www.forbes.com/sites/normananderson/2021/05/19/the-fourth-industrial-revolutionkorea-invests-20-billion-in-its-smart-city-ecosystem/

[3] Patent families where at least one member is still a patent application or a granted patent are considered as alive.

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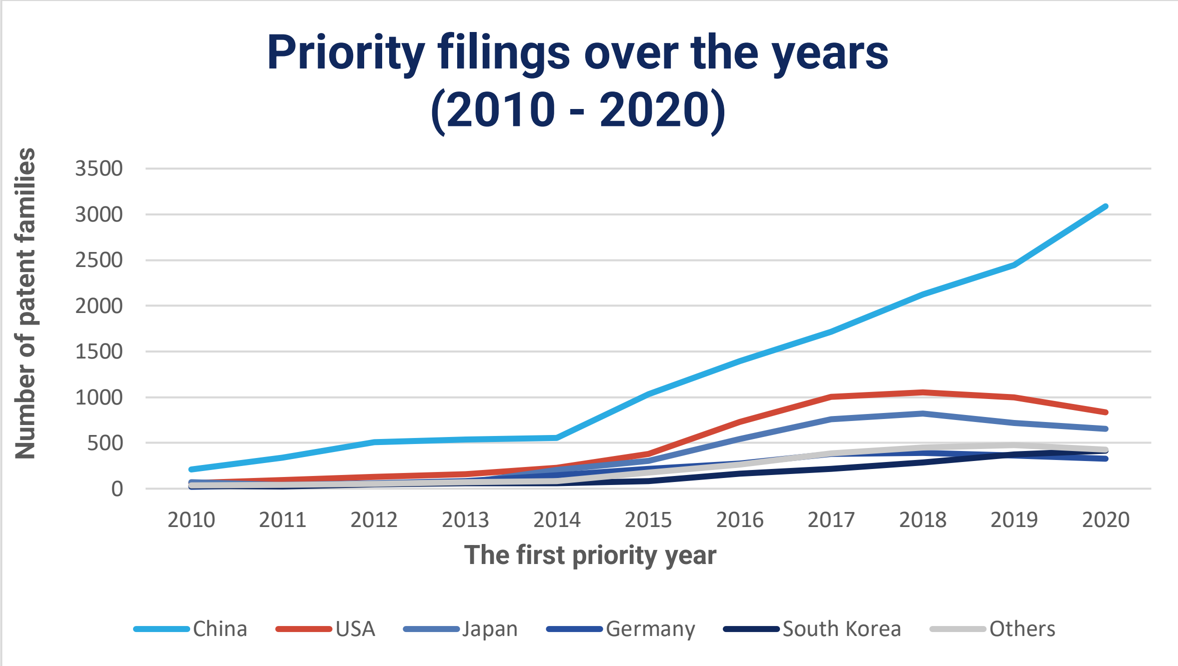

Figure 26 – ST Top 5 priority country patent filing dynamics

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Patent landscape

Smart Transportation

Market countries

China, main market country

Publication countries is one of the indicators that reflects targeted markets by different players, markets that need to be protected as per the players' protection strategy. However, the publication geographical areas may not be restricted to just potential markets, they may also represent the location of competitors manufacturing sites where inventions need also to be protected.

The map below represents the number of published patent families per area depending on the Offices practices.

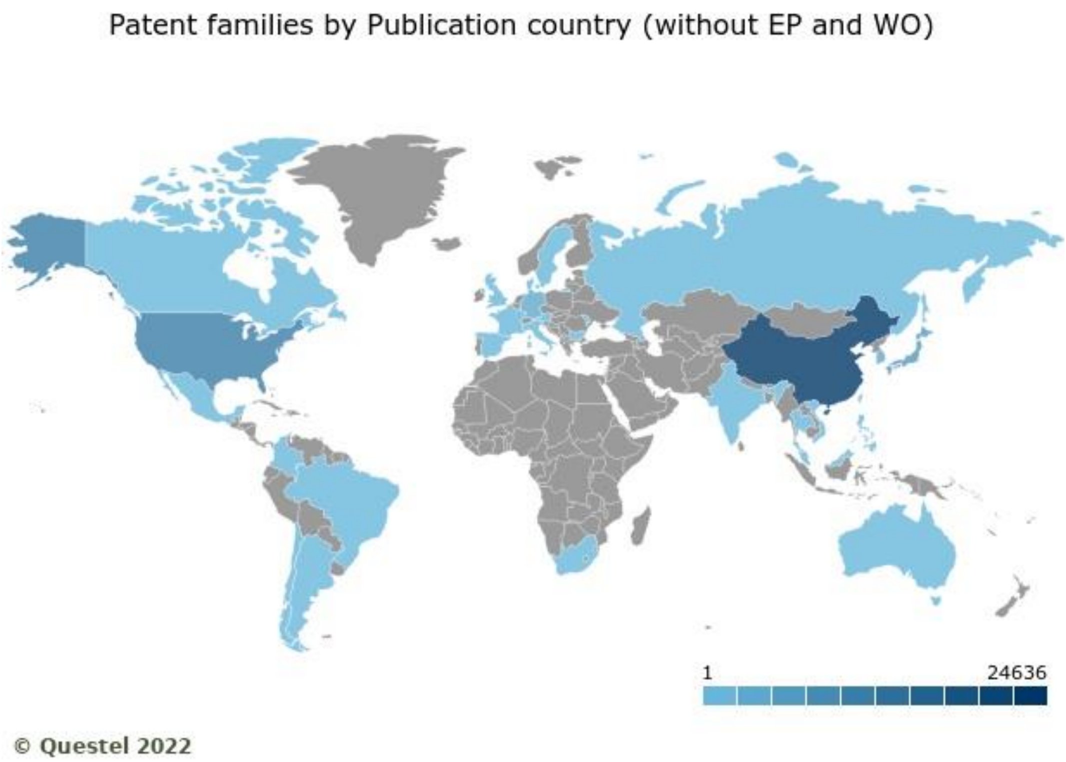

Figure 27 – ST Worldwide patent families by publication country

38% of patent families have been published in China, a number that demonstrates the importance of China as major market. However, this high percentage is also strengthened by the big Chinese patent activity as seen in the previous section[1],

[1] Refer to the First Priority Country graph

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where 46% of Smart Transportation related filing activities comes from China. USA and Japan follow with 17% and 10% respectively.

Most of the Chinese patent applications are only published in China, and only 3.5% of Chinese applications are extended in the USA, the largest Western market country for Chinese patents. In fact, other territories such as Europe, Japan and South Korea follow with only 2.4%, 2.1% and 1.4% of the total that are far ahead any other extension market. India position after South Korea could be related to the growth business opportunities in this country created by the Indian government's plan to establish 100 smart cities.

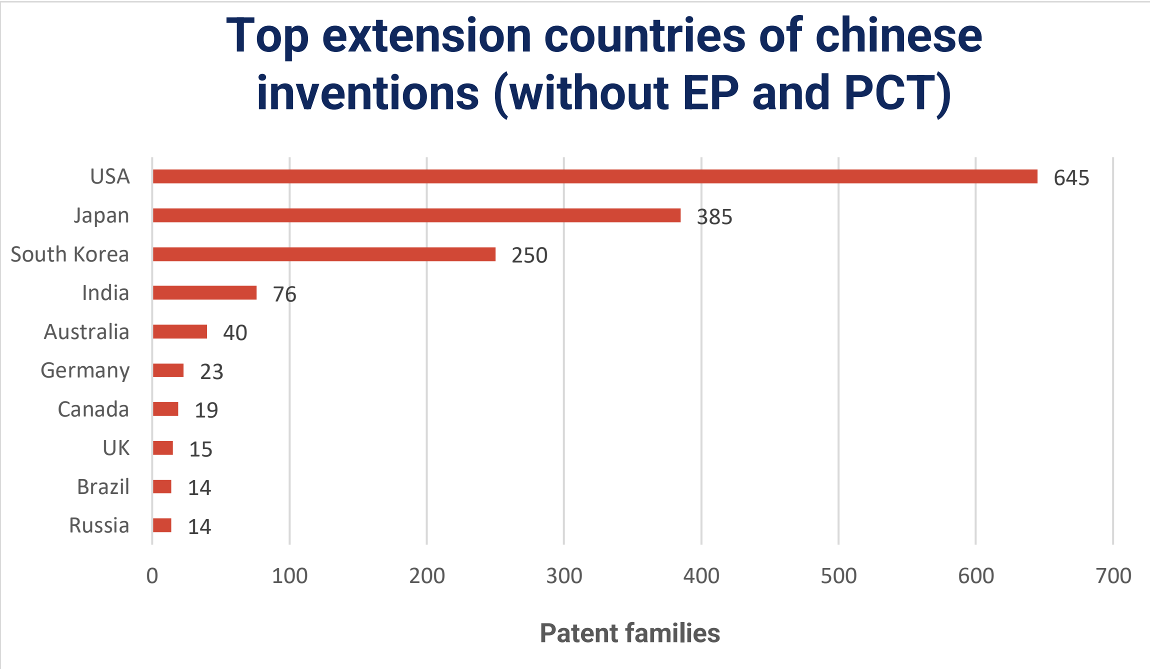

Figure 28 – ST Top Extension Countries of Chinese Inventions

On the other hand, 26% of American patents have been extended in China, whereas 22% have been published in Europe, which reflects the American strategy in terms of protection and extension to large consumer markets. Interestingly, other countries, such as Japan and Germany tend to equally protect their inventions in both USA and China, while South Korea protect their inventions more than twice as often in the USA than in China which can point to the strong importance of the American market to the South Korean.

Patent landscape

Smart Transportation

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Players

35% of total inventions in Smart Transportation comes from the top 50 players (12,683 patent families) and 17% from the top 10 (6,187 patent families). The domination of automotive specialized or related activities companies is obvious in the field with 30 players out of 50. The share of the academic in the top 50 is restricted to 10 players, all Chinese, which could be a sign of the maturity of this field and an indication of a great interest of the industry in this extremely high trendy domain, where many projects have been launched in different countries. Moreover, the interest in the field is spread over different geographic areas with 16 Chinese players (including 10 academic), 11 American (all industrial), 9 Japanese, 6 German and 4 South Korean. The variety in players typography can also be noticed as electronics, semi-conductor, Internet and telecommunications, among others, are all major key technology fields for smart transportation.
The top patent filer in smart transportation is the Japanese automotive manufacturer Toyota with 3.6% of total number of patent families. This number reflects the high investment of the company in the field. Toyota's smart city project the Woven City[1], with the construction inaugurated in January 2021, is another proof of the extremely high ambitious goals of the company. The Chinese giant, Baidu second position with 2.8% share of inventions is not less important and reflects its leading position in smart transportation as it is for autonomous vehicles with Baidu Apollo high involvement in three major fields, autonomous driving, smart cars and smart transportation. This number mirrors the company's vision[2] as to become a global leader in the intelligent driving industry.
Among the top 10 players, 3 come from outside the automotive industry: BAIDU is second, LG ELECTRONICS is 7th and HUAWEI 8th with a global share of patent families of 2.8%, 1.4% and 1% respectively. The tight race between countries can be also clearly noticed with the diversity of top players, Japanese, Chinese, American and German.

[1] https://www.woven-city.global/
[2] https://www.apollo.auto/aboutus

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TOP 50 APPLICANTS LIST			
Assignees	Number of inventions	Country	Player Typography
TOYOTA MOTOR	1293	Japan	Automotive manufacturer
BAIDU	1013	China	Internet and technology
HONDA MOTOR	664	Japan	Automotive manufacturer
ROBERT BOSCH	620	Germany	Automotive supplier
FORD GLOBAL TECHNOLOGIES	566	USA	Automotive manufacturer
DENSO	511	Japan	Automotive supplier
LG ELECTRONICS	489	South Korea	Electronics company
HUAWEI	359	China	Telecommunications
GM GLOBAL TECHNOLOGY OPERATIONS	351	USA	Automotive manufacturer
BMW - BAYERISCHE MOTOREN WERKE	321	Germany	Automotive manufacturer
NISSAN MOTOR	310	Japan	Automotive manufacturer
HYUNDAI MOTOR	304	South Korea	Automotive manufacturer
DAIMLER	299	Germany	Automotive manufacturer
WAYMO	291	USA	Automotive manufacturer
VOLKSWAGEN	260	Germany	Automotive manufacturer
AUDI	245	Germany	Automotive manufacturer
SOUTHEAST UNIVERSITY	227	China	Academic
MITSUBISHI ELECTRIC	224	Japan	Automotive supplier
PANASONIC INTELLECTUAL PROPERTY MANAGEMENT	214	Japan	Electronics company
TENCENT TECHNOLOGY SHENZHEN	194	China	Internet and Technology
TSINGHUA UNIVERSITY	193	China	Academic
TONGJI UNIVERSITY	176	China	Academic
INTEL	169	USA	Chip manufacturer
SUBARU	168	Japan	Automotive manufacturer
JILIN UNIVERSITY	165	China	Academic
CHONGQING UNIVERSITY	163	China	Academic
KIA MOTORS	160	South Korea	Automotive manufacturer
CHANG'AN UNIVERSITY	145	China	Academic
BEIJING UNIVERSITY OF TECHNOLOGY	142	China	Academic
HERE GLOBAL	142	USA	Automotive map and location solution
ZOOX	141	USA	Automotive manufacturer
VALEO SCHALTER & SENSOREN	140	France	Automotive supplier
RENAULT	136	France	Automotive manufacturer
HYUNDAI MOBIS	131	South Korea	Automotive supplier
CHONGQING CHANGAN AUTOMOBILE	130	China	Automotive manufacturer
ZF FRIEDRICHSHAFEN	124	Germany	Automotive supplier
BEIHANG UNIVERSITY OF AERONAUTICS & ASTRONAUTICS	123	China	Academic
JIANGSU UNIVERSITY	122	China	Academic
GENVICT	116	China	Intelligent transportation services
MOTIONAL	116	USA	Automotive manufacturer
UATC	115	USA	Software services
VENIAM	114	USA	Internet of Moving Things
PSA AUTOMOBILES	109	France	Automotive manufacturer
QUALCOMM	105	USA	Telecommunications, Chip manufacturer
HITACHI ASTEMO	104	Japan	Automotive supplier
APTIV TECHNOLOGIES	100	USA	Automotive technology supplier
ZHEJIANG GEELY HOLDING GROUP	98	China	Automotive manufacturer
WUHAN UNIVERSITY OF TECHNOLOGY	95	China	Academic
PIONEER ELECTRONIC	94	Japan	Electronics company
IBM	92	USA	Computer hardware,software and services

Table 3 – Top 50 Applicants of Smart Transportation -Related Patents

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Trends in the industrial sector

Focusing on the top 50 industrial players, USA takes the first position in terms of number of companies (11 players). It is not surprising to see that most of those actors come from the automotive industry with two giants at the top, FORD and GENERAL MOTORS having a 40% share of the 11 top American Players' inventions. However, the diversity of players cannot be overlooked, with big names such as IBM from the information technologies, INTEL from the semiconductors industry, QUALCOMM from telecommunications, HERE GLOBAL for map and location solutions, and UATC Uber Advance Technologies Center for software services.

Indust. Rank	Player	Patents
32	VALEO SCHALTER & SENSOREN	140
33	RENAULT	136
43	PSA AUTOMOBILES	109

Indust. Rank	Player	Patents
4	ROBERT BOSCH	620
10	BMW - BAYERISCHE MOTOREN WERKE	321
13	DAIMLER	299
15	VOLKSWAGEN	260
16	AUDI	245
36	ZF FRIEDRICHSHAFEN	124

Indust. Rank	Player	Patents
5	FORD GLOBAL TECHNOLOGIES	566
9	GM GLOBAL TECHNOLOGY OPERATIONS	351
14	WAYMO	291
23	INTEL	169
30	HERE GLOBAL	142
31	ZOOX	141
40	MOTIONAL	116
41	UATC	115
42	VENIAM	114
44	QUALCOMM	105
46	APTIV TECHNOLOGIES	100
50	IBM	92

Indust. Rank	Player	Patents
1	TOYOTA MOTOR	1293
3	HONDA MOTOR	664
6	DENSO	511
11	NISSAN MOTOR	310
18	MITSUBISHI ELECTRIC	224
19	PANASONIC	214
24	SUBARU	168
45	HITACHI ASTEMO	104
49	PIONEER ELECTRONIC	94

Indust. Rank	Player	Patents
7	LG ELECTRONICS	489
12	HYUNDAI MOTOR	304
27	KIA MOTORS	160
34	HYUNDAI MOBIS	131

Indust. Rank	Player	Patents
2	BAIDU	1013
8	HUAWEI	359
20	TENCENT TECHNOLOGY SHENZHEN	194
35	CHONGQING CHANGAN AUTOMOBILE	130
39	GENVICT	116
47	ZHEJIANG GEELY HOLDING GROUP	98

Figure 29 – Smart Transportation Top 50 Word Distribution

The involvement of the tech giant GOOGLE and its parent company, ALPHABET can also be noticed with its self-driving vehicle subsidiary WAYMO and its share of 291 inventions, giving it the 3rd position for American companies and the 14th worldwide, ahead of various players such as VOLKSWAGEN, AUDI, SUBARU and RENAULT. INTEL's[1] position as the 4th American company, can be justified with its involvement in self-driving solutions with Mobileye and its 2030 RISE technology industry initiatives for AV to enhance traffic security. The American start-up VENIAM 42nd global position displays its fierce activity on vehicle

[1] https://csrreportbuilder.intel.com/pdfbuilder/pdfs/CSR-2021-22-Full-Report.pdf#page=44

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networks (Internet of Moving Things) since its foundation in 2012 where it reached a portfolio of 150 patents in just five years (2017).

The Japanese automotive companies' high involvement is noticed as with Americans with names such as TOYOTA, HONDA, NISSAN, and SUBARU. Only 9% of top 9 Japanese players inventions comes from Electronics companies (PANASONIC, PIONEER).

European inventions, both German and French are restricted to the automotive industry while the top industrial South Korean player is LG Electronics from the electronics industry.

Among the top listed 50 companies, the only exception is represented by Chinese companies, where most inventions (82% of the top 6 industrial players) come from different sectors of the industry than automotive such as Internet and telecommunications, with BAIDU, HUAWEI and TENCENT.

Increase in patent filings trends for the top 5 players can be observed between 2013 and 2015. While ROBERT BOSCH number of inventions' steep increase started in 2013, this trend started 2 years later for BAIDU. TOYOTA MOTORS kept its leadership in number of yearly patents with a high growth rate of 24% between

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2015 and 2020. Despite this first position for TOYOTA, the appearance of BAIDU who was almost absent before 2014 is quite impressive, where an explosive growth of 119% was registered from 2015 to 2020. This extremely high growth demonstrates the high investment of the company in the field and reflects the Chinese government new policies[1] to create a favourable environment for smart transportation development. Those policies helped to foster new initiatives and projects that work on accelerating the deployment of Smart Transportation in the country.

The lowest CAGR rate registered for the top 5 industrials is for ROBERT BOSCH with only 5% (2015-2020). FORD decline in filing activities was noticed starting 2018 despite a growth rate of 8% between 2015 and 2020. HONDA's peak increase was in 2016 where the number of filings was more than 10 times the previous year. HONDA's investment in Smart Transportation is also important where a CAGR of 42% was registered for the company for the same period (2015-2020).

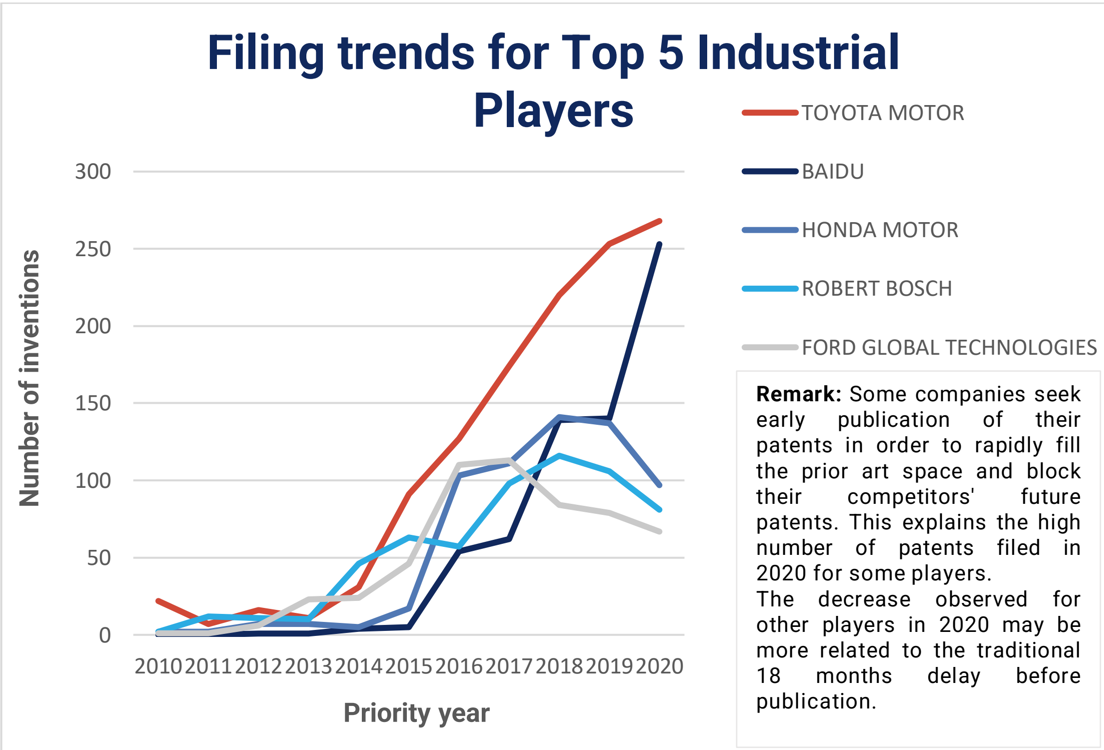

Figure 30 – ST Top 5 Industrial Players Filing Trends

Patents portfolio's strength and impact

The same indicators (Patent citations, technological diversity, etc.) used in evaluating technological capabilities and performance for Autonomous Driving

[1] http://civitas.eu/news/smart-transportation-in-china-what-is-the-current-situation

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actors, are used as a measure to assess the positions of firms in smart Transportation.

Comparing competitors' technological impact and portfolio value by referring to the following graph (*Figure 31 - Smart Transportation Player's Impact*) shows that:

- Toyota holds the highest portfolio value across all competitors identified in the Smart Transportation field, closely followed by Baidu. The tight competition between Toyota and Baidu can't but be noticed when it comes to the first two positions in Autonomous Driving and Smart Transportation. The same actors, Ford, Honda and Robert Bosch follow with lesser indicator's values as it was for self-driving.
- Ford being the pioneer in terms of impact is remarkable as again the company is holding the highest technological impact ranking as it was for Autonomous Driving.

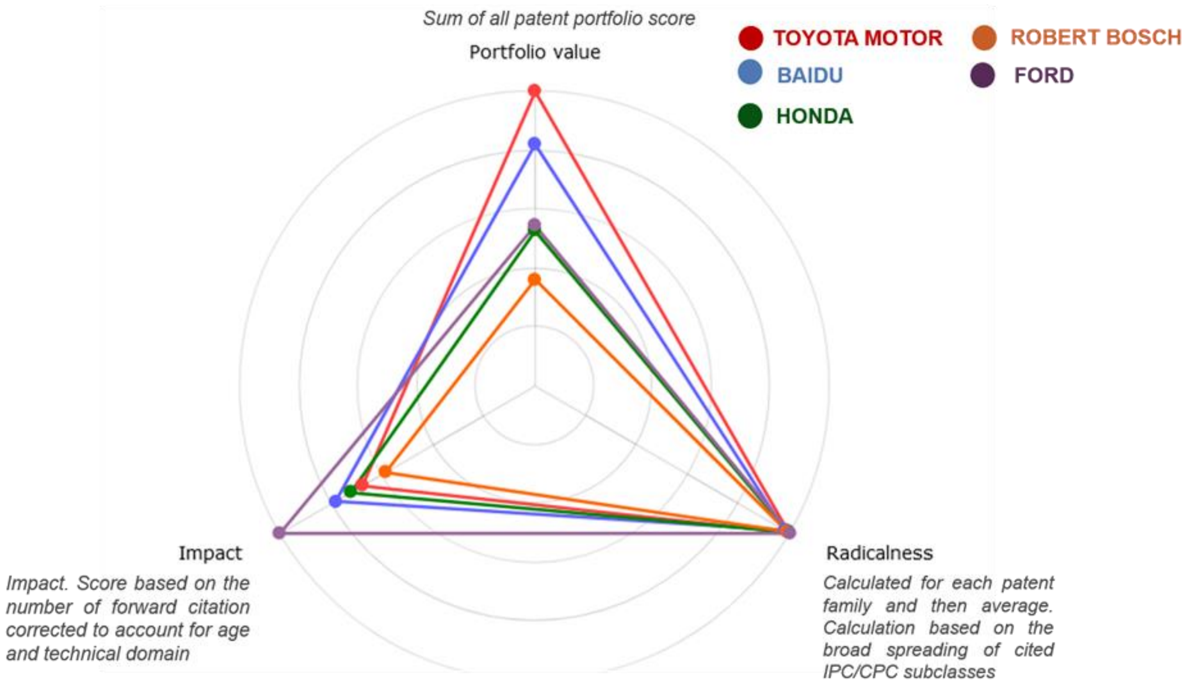

Figure 31 – Smart Transportation Player's Impact

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A closer analysis of top actors' patents portfolios technical influence (*Table 4 - Smart Transportation Impactful Patents per actor*), Toyota, with its long history in the field, holds again the top position. Baidu's newest entry does not only mark the field with the big number of filing and its growth rate, but also with the value and the impact of the company's inventions in the innovation world.

- **Impactful patent** is the count of patent families with at least one non-self forward citation.
- **Interfering patents** is the count of patent families cited by an examinator for questioning the patentability or inventive of a patent application
- **Forward X** is the count of patent families cited by an examinator as category "X"
- **Forward Y** is the count of patent families cited by an examinator as category "Y"

	Impactful patent	Interfering patents	Forward X	Forward Y
TOYOTA MOTOR	753	355	228	308
BAIDU	552	305	184	251
HONDA MOTOR	439	246	135	219
ROBERT BOSCH	377	169	118	125
FORD GLOBAL TECHNOLOGIES	454	236	158	198
DENSO	322	208	134	188
LG ELECTRONICS	324	125	86	96
HUAWEI	225	108	81	74
GM GLOBAL TECHNOLOGY OPERATIONS	343	153	119	126
BMW - BAYERISCHE MOTOREN WERKE	183	73	48	50
NISSAN MOTOR	230	129	80	114
HYUNDAI MOTOR	191	66	43	49
DAIMLER	155	53	29	44
WAYMO	242	135	107	119
VOLKSWAGEN	174	76	61	55
AUDI	165	71	53	60
SOUTHEAST UNIVERSITY	151	73	31	65
MITSUBISHI ELECTRIC	131	86	48	78
PANASONIC INTELLECTUAL PROPERTY MANAGEMENT	145	91	50	80
TENCENT TECHNOLOGY SHENZHEN	91	41	27	35

Table 4 – Smart Transportation Impactful Patents per actor

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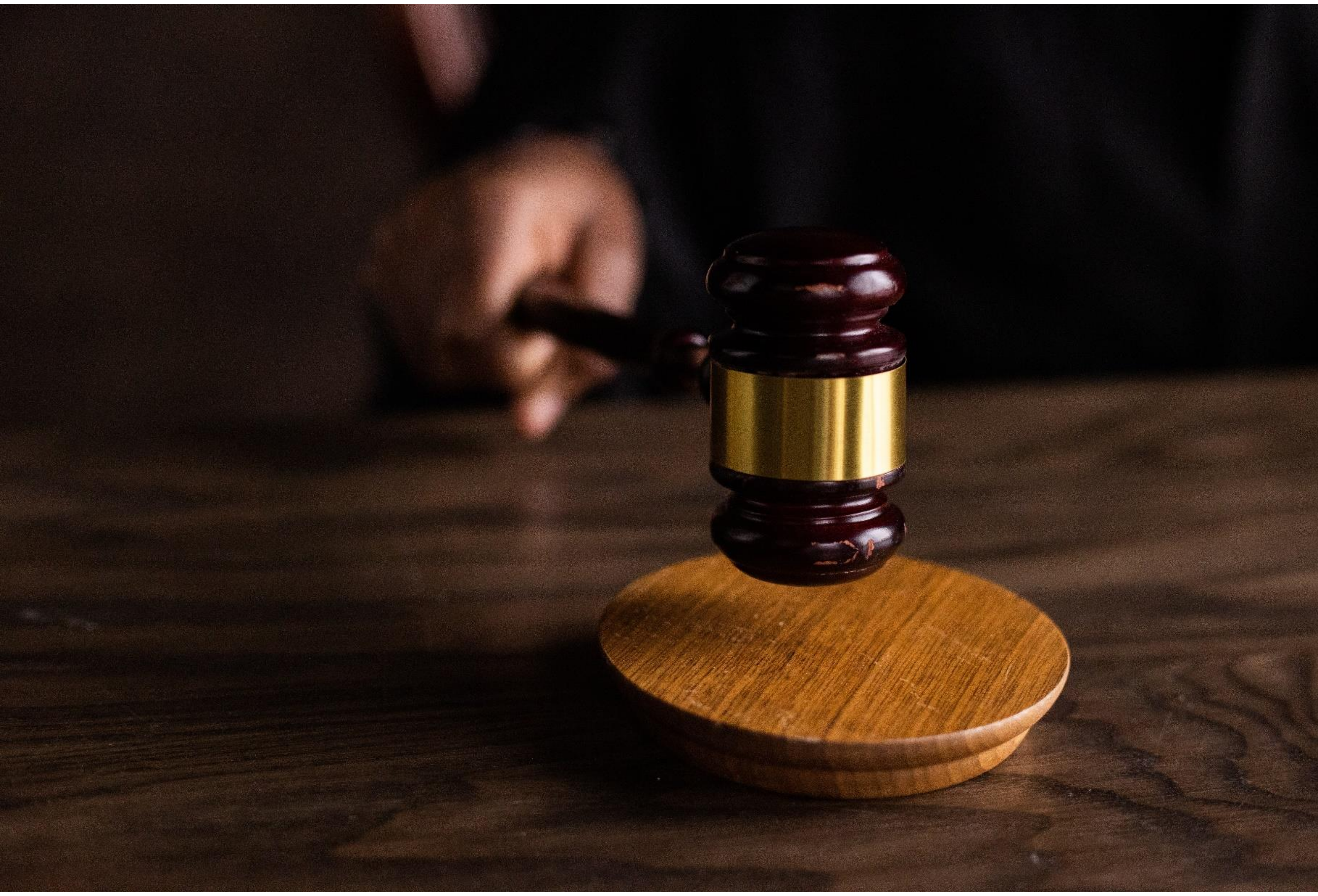
Unaggressive field

Only 11 infringement related litigations have been observed out of around 36 K patent families, 6 in the US, 4 in Germany and 1 in China. A very low number when compared to the total number of patent families and to number of infringements in other technical fields. This number may be predisposed to increase when Smart Transportation is widely deployed. Litigation may be even wider when considering that inventions don't just come from traditional car manufacturers and suppliers but rather involves a variety of technical fields such as IT and telecommunications.



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Patent landscape

Smart Transportation

Segmentation analysis

Vehicle-road collaboration cloud platform

Cloud-based services have been implemented for a wide range of application areas. To deal with the massive amounts of data generated, cloud computing is being invested in to face traffic issues present in smart cities environments and more precisely in smart transportation.

This investment is portrayed by the 4,137 patent families (~11.5% of the global Smart Transportation database) related to the collaboration between vehicles and their surrounding using cloud platforms.

A high, steady, and steep increase in patent filings started since 2014 with a CAGR of 51% between 2014 and 2020. This increase could be justified by the speedy advances in wireless telecommunications and in IoT, which both are key factors

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to ensure the communication exchange needed between the self-driving vehicles and cloud-based systems.

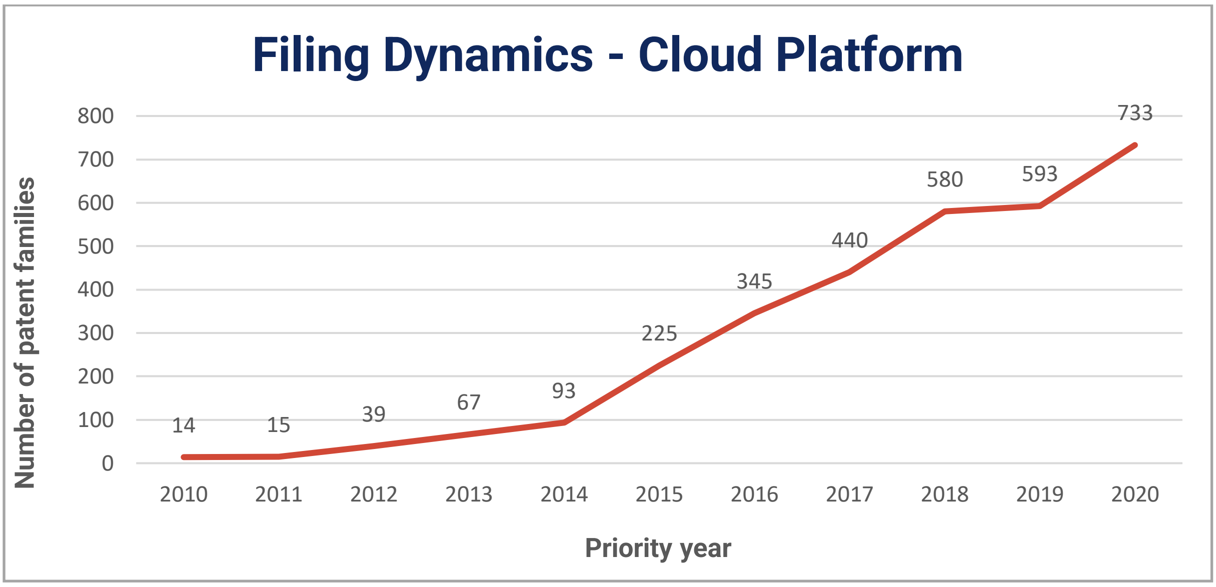

Figure 32 – Vehicle-road collaboration cloud platform Filing Dynamics

Among the top 10 geographic areas, China is way ahead any other country with 74% of the inventions followed by the USA with 14%. One of the top 4 comer in this specific segment is India where the country is launching many projects to address Indian traffic issues and where the government is planning to establish 100 smart cities. The appearance of India aligns with the publication of the Office of the Principal Scientific Adviser to the Government of India[1], where it was stated that the future of the Indian transport industry will be carved by radical transformations through major disruptive technologies based on Intelligent transport systems driven by Industry 4.0, data analytics, IoT, and artificial intelligence from hyperloop to autonomous and remotely piloted vehicles. Germany, India, South Korea, and Japan contribute with around ~2% each, while other regions who come behind have ~1% or less of contribution. This leads to the conclusion that the R&I activities are mainly guided by China followed by the USA.

[1] https://www.psa.gov.in/technology-frontiers/future-transportation/690

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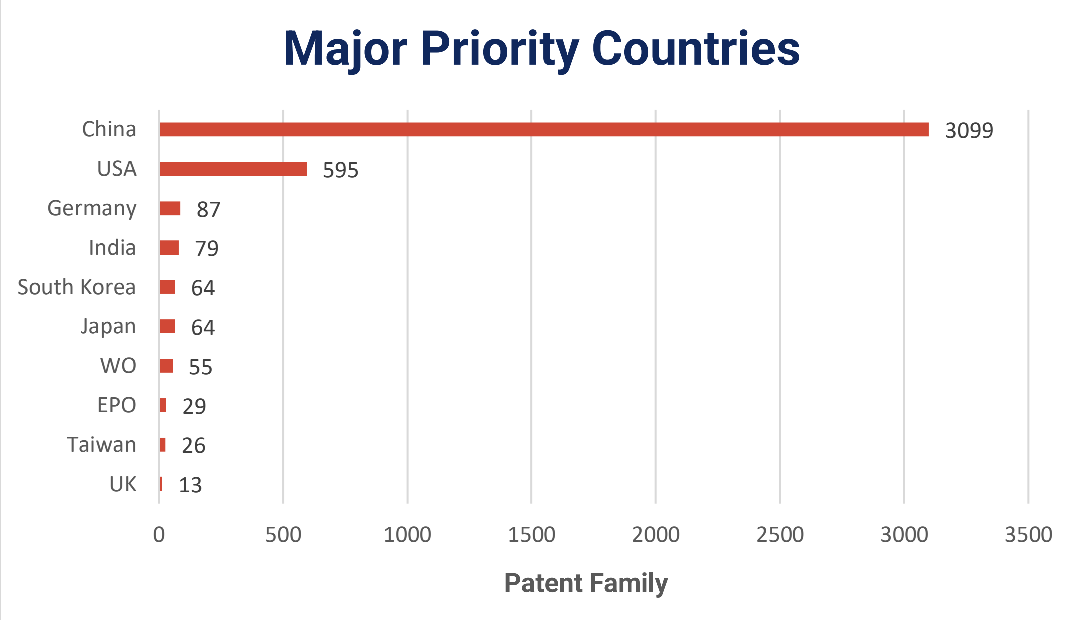

Figure 33 – Vehicle-road collaboration cloud platform Main Priority Countries

Among the top 10 players the Chinese player BAIDU is ahead with 4.5% of inventions. However, though Japan is not among the top 3 countries, TOYOTA managed to keep the second place with 1.8% of patent families. The top industrial players positions are shared between China and the USA with 4 companies each and only one Chinese academic, TSINGHUA UNIVERSITY, is present in the 9^{th} position.

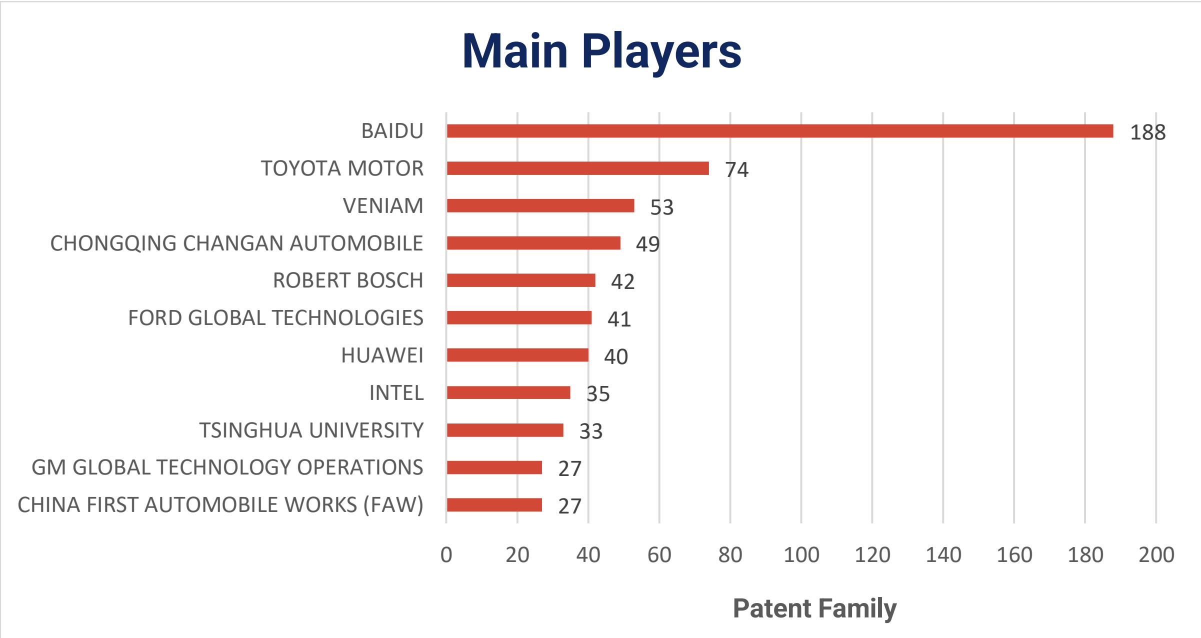

Figure 34 – Vehicle-road collaboration cloud platform top players

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Roadside equipment

Environmental awareness is the basis for intelligent driving techniques, however vehicle sensing devices are limited due to factors such as fixed position or limited visual angle. Intelligent driving roadside equipment are used to assist vehicle driving in having a more comprehensive environmental information and therefore enhance prediction's accuracy. As significant growth in applying modern technologies in vehicles and transportation infrastructure is taking place, investment in roadside computing equipment is flourishing.

~10.5K patent families which corresponds to 29% of the global Smart Transportation database, has been filed since 2010 and a CAGR of 38% has been registered from 2014 to 2020.

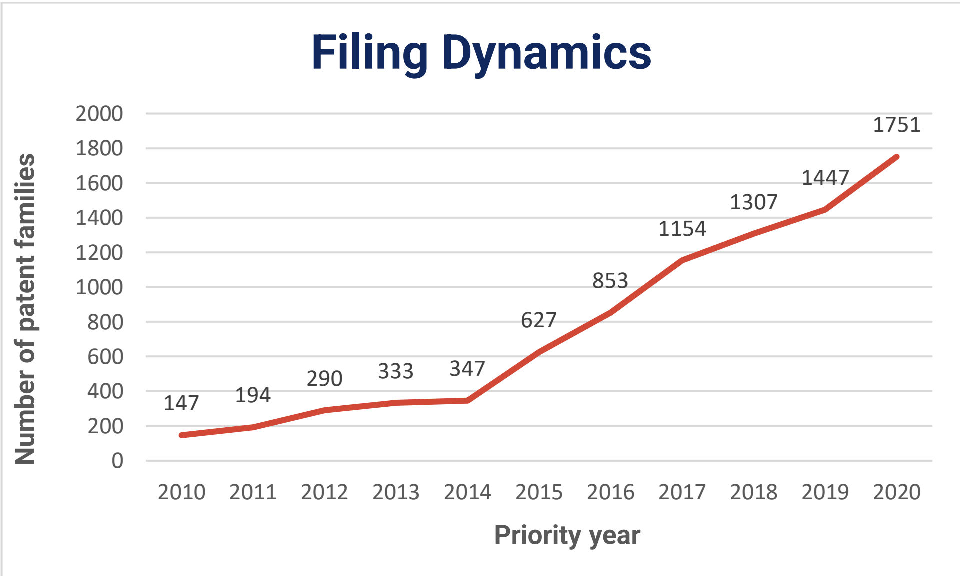

Figure 35 – Roadside equipment Filing Dynamics

As with cloud-based platforms, the domination of Chinese inventions is way ahead other regions with 70% share of patent families. Japanese come second, demonstrating a higher implication in smart roadside devices than other segments. 9% of inventions come from Japan, this number reflects a high concurrence between the Japanese and the Americans who are ranked 3rd with an 8% share, being therefore behind with only 1% of filed patents.

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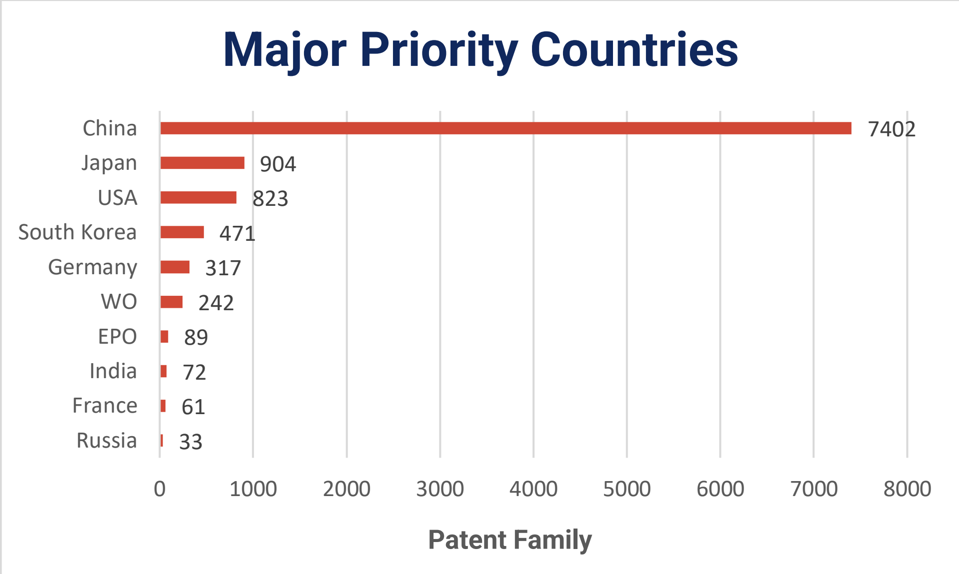

Figure 36 – Roadside equipment Main Priority Countries

Surprisingly, none of the top players is American, however four are Japanese, with TOYOTA being second, while four industrial Chinese players are listed with BAIDU keeping the first place. Japanese top 4 players generated together 5% of the inventions while the Chinese giant BAIDU had alone a percentage of around 4%.

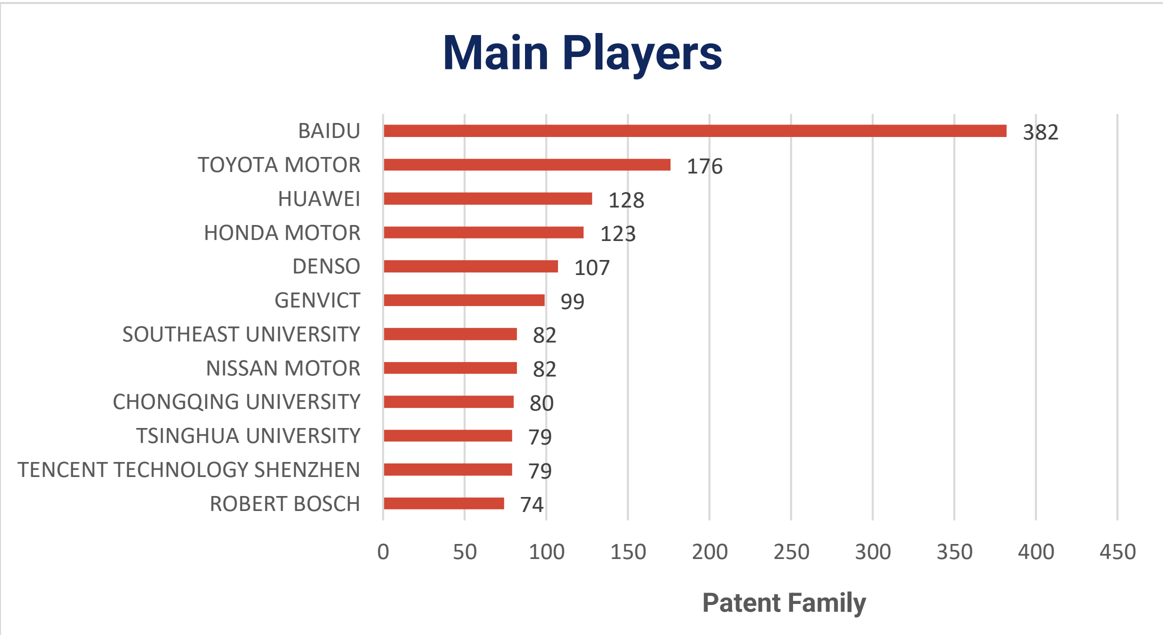

Figure 37 – Roadside equipment Top Players

Traffic lights and traffic control

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Processing traffic information and managing traffic congestion and traffic overflow at intersections with intelligent traffic lights is another field of investment. 12,681 subject related patents have been filed which represents a 35% of Smart Transportation inventions found in this analysis. 2014 has been again a milestone for the increase in number of inventions where a growth rate of 32% has been recorded from 2014 to 2020.

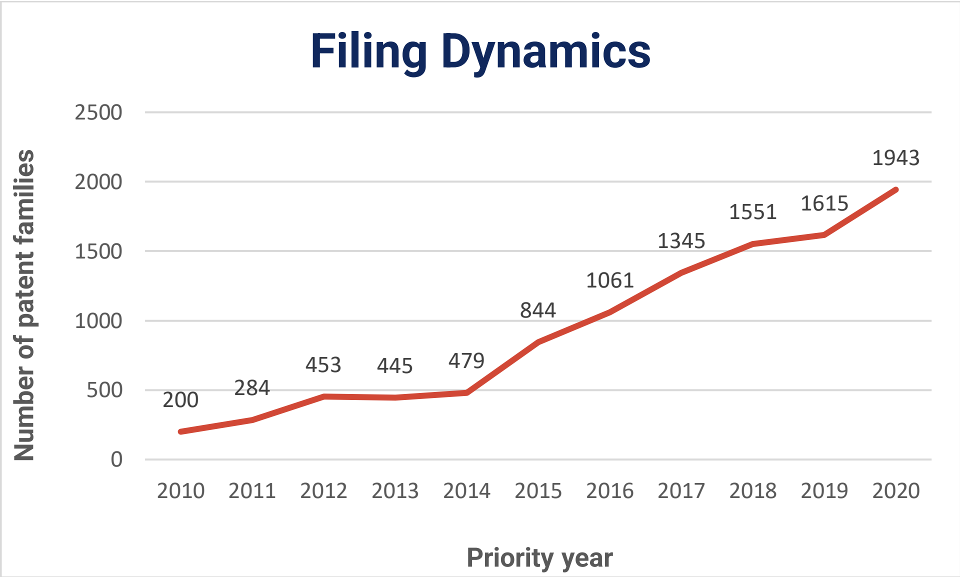

Figure 38 – Traffic lights and traffic control Filing Dynamics

The same countries as for the global Smart Transportation have retained the top 5 positions in R&D activities in this specific technical field with China, USA, Japan, South Korea, and Germany. China domination is again and again detected with a huge share of 76% followed by the USA with 8% and Japan with 4%.

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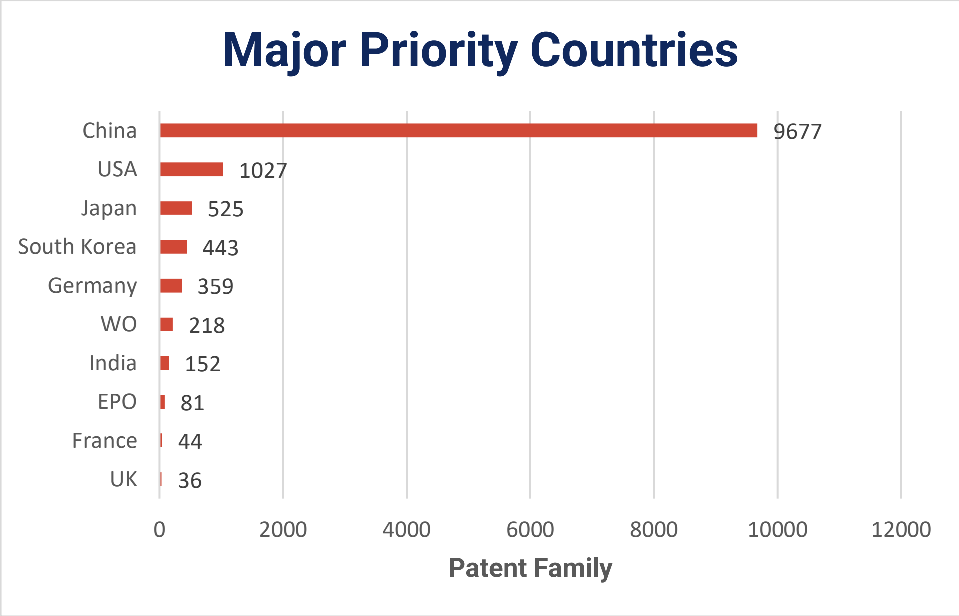

Figure 39 – Traffic lights and traffic control Main Priority Countries

The presence of many universities in the top players is something that differentiate this segment from Cloud and Road Equipment segments. 5 out of the top 10 actors and 8 of the top 15 are Chinese academics, which could be a sign of the low maturity of the field. The top 3 industrials are BAIDU with 3% share followed by TOYOTA and HUWAEI with ~1% each. The top 15 industrial players are restricted to Chinese and Japanese players, except for the German ROBERT BOSCH which holds the 15th position.

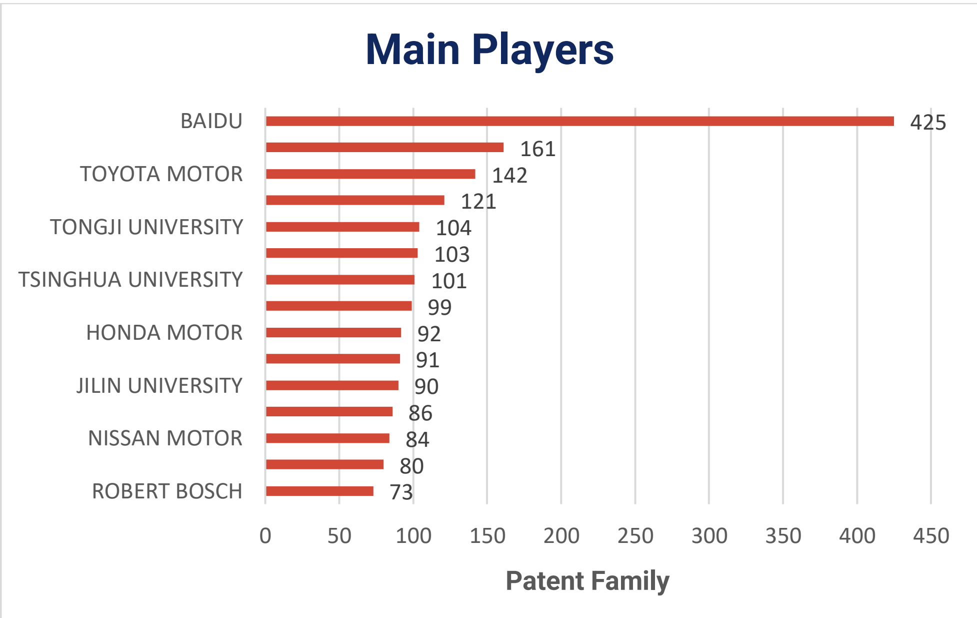

Figure 40 – Traffic lights and traffic control Top Players

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Smart Transportation – Others

Smart Transportation combines numerous aspects, such as hardware, software, and mobile network components. Machine learning/data analytics, IoT, and cybersecurity are all some of the technological fields taking part of the development of Smart Transportation. Collaboration between public infrastructure and the automotive industry is what makes intelligence into transportation possible. Among the many various other fields existing, 16,411 patent families have been filed which corresponds to 46% portion.

A growth rate of 34% is recorded from 2014 to 2020, however a peak of saturation is noticed starting 2018. This plateau could point to the maturity of the technical fields covered in this segment and highlights the focus of the R&D efforts in the three booming categories, cloud platforms, roadside equipment, and traffic lights & control.

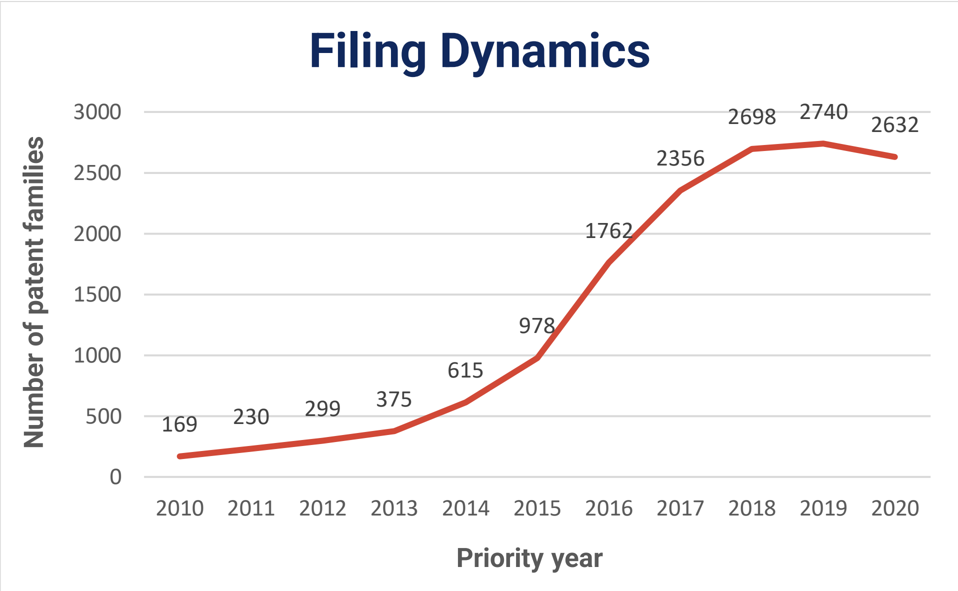

Figure 41 – Smart Transportation -Others -Filing Dynamics

The first top 3 countries, China, USA and Japan contributes with about similar percentage of number of inventions, with 28%, 24% and 20%respectively, highlighting the tight rivalry among those countries for innovation supremacy

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in this technological field as it is also with many other fields. China, Japan and South Korea ranking among the top 5 aligns with the Asia Pacific market Smart Transportation growth forecast published by Grand View Research[1] where the region is expected to grow at the highest CAGR over 2022 to 2030 owing to government initiatives. Countries such as China, India, South Korea, and Japan (among the Top 10 players) are witnessing higher growth rates compared to the countries in the rest of the world and this always according to the prementioned market analysis report (Historical Range: 2017 – 2020). Grand Review Research report also mentioned the high North American market share fostered by growing government investments in transportation infrastructure and the presence of significant opportunities for industry expansion in the European region reflected by the presence of three European countries, Germany (11%), France and the UK along with the European Patent Office among the top 10 players.

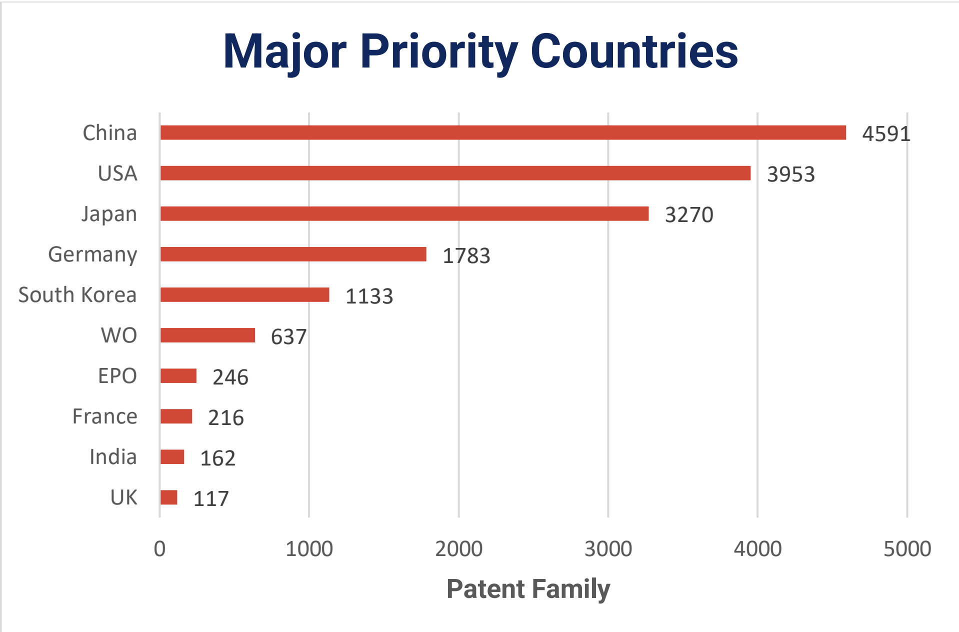

Figure 42 – Smart Transportation -Others -Main Priority Countries

The first position of the Japanese player TOYOTA (6%) reflects its long time of investment in the field. All top 15 players are automotive industrials coming from the top 5 countries (China, USA, Japan, Germany and South Korea), except the

[1] https://www.grandviewresearch.com/industry-analysis/smart-transportation-market

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electronics south Korean company LG which holds the 5th position with a 2.6% share.

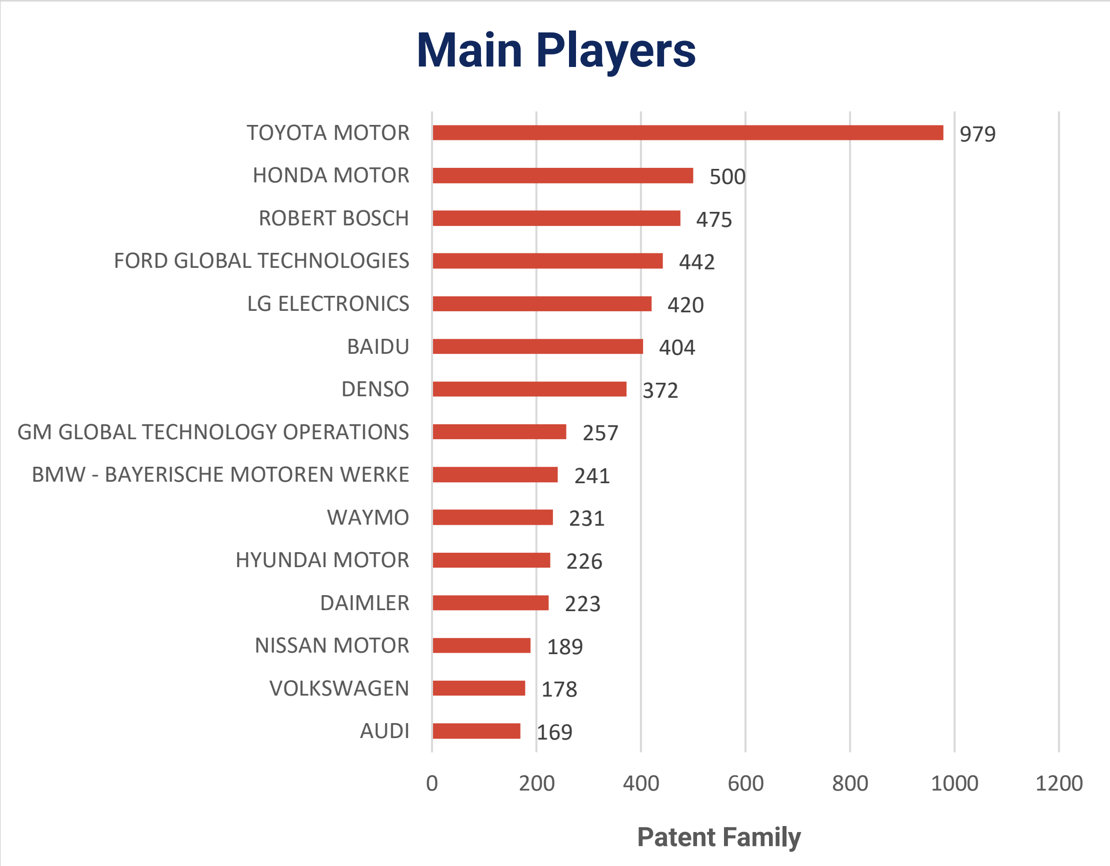

Figure 43 – Smart Transportation -Others- Top Players

Many players already joined forces to develop a technology that requires a variety of elements. Daimler for example had an agreement with Bosch, the largest automotive supplier on the planet, laying out the plan to launch a system that is fully automated (SAE-Level 4) and driverless (SAE-Level 5). The Volkswagen Group is developing self-driving capabilities in-house with AUDI Piloted Driving being at the technological forefront of the group. BMW signed an agreement with INTEL to leverage the artificial intelligence capabilities of WATSON[1].

Appendices

[1] https://combined-transport.eu/autonomous-vehicle-market

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ANNEX A – TAXONOMY

Technology segments explained

High-precision map and positioning	A High-precision map called also high-definition map (HD map) is a highly accurate map used in autonomous driving, containing details not normally present on traditional maps. Such maps can be precise at a centimetre level. HD maps are often captured using an array of sensors, and GPS. High-definition maps for self-driving cars usually include map elements such as road shape, road marking, traffic signs, and barriers.
Perception	The perception in self-driving cars consist of using a combination of high-tech sensors, such as thermographic cameras, radar, lidar, sonar, GPS, odometry and inertial measurement units, to perceive the environment around the vehicles, in real-time.
Planning, decision-making and control	Planning, decision-making and motion control consist of using data from the HD map and the perception units to form the basis for generating a trajectory that serves as a target value to be followed by a controller.
Vehicle-road collaboration cloud platform	It is a web-based traffic management ecosystem that accesses, monitors, and manages the massive amounts of data generated to deal with the traffic challenges present in smart city environments and more specifically in smart transportation.
Roadside equipment	Roadside equipment are used to assist vehicle driving in having a more comprehensive environmental information and therefore enhance prediction’s accuracy.
Traffic lights and traffic control	Smart traffic lights or Intelligent traffic lights are a vehicle traffic control system that combines traditional traffic lights with an array of sensors and artificial intelligence to intelligently route vehicle and pedestrian traffic.

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Industries explained

Transportation	Automobiles, vehicles, Autonomous Vehicle, (AV), Autonomous Driving (AD) etc.
Telecommunications	3G, 4G, 5G networks, Internet of Things (IoT), Vehicle-to-Vehicle (V2V), Vehicle-to-Everything (V2X) etc.
Internet, search engine& software services	Software systems, Operating systems, Cloud computing, Servers, Databases etc
Electronics	Electronic devices, Microprocessors, Chips manufacturing, Integrated circuit, Sensors etc.
Computer	Hardware, Digital machine, peripheral equipments etc

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ANNEX B – GLOSSARY

- **Patent family (Fampat)**: defined as an "invention-based family", this family definition from Questel incorporates the EPO's strict family rule (same priority application(s)) with additional rules (applications falling outside the 12 months filing limit; links between EP and PCT publications…) etc. A reasonable compromise between strict family and extended family.
- **Patent application**: to obtain a patent, an application must be filed in the appropriate Patent Office with all the necessary documents and fees. The patent office will conduct an examination to decide whether to grant or reject the application. Patent applications are generally published 18 months after the earliest priority date of the application. Prior to that publication, the application remains confidential.
- **Granted patent**: once examined by the patent office, an application becomes a granted patent or is rejected. If granted, the patent gives his owner a temporary right for a limited time period (normally 20 years) to prevent unauthorized use of the technology outlined in the patent. Procedure for granting patents varies widely between countries according to national laws and international agreements. Note that in the same patent family, an application can be granted in one country and rejected in another.
- **PCT (WO)**: The Patent Cooperation Treaty (PCT) is an international patent law treaty concluded in 1970, administered by the World Intellectual Property Organization (WIPO), between more than 140 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single "international" patent application instead of filing several separate national or regional patent applications. The granting of patents remains under the control of the national or regional patent offices in which is called the "national phase".
- **European patent (EP)**: a European patent can be obtained for all the EPC countries by filling a single application at the EPO in one of the three official languages (English, French or German). European patents granted by the EPO have the same legal rights and are subject to the same conditions as national patents (granted by the national patent office). A granted European patent is a "bundle" of national patents, which must be validated at the national patent office to be effective in member countries. The validation process could include submission of a translation of the specification, payment of fees and other formalities at the national patent office. Once a European patent is granted, competence is transferred to the national patent offices. Other regional patents or procedures also exist: the Eurasian patent (EA), ARIPO patent (AP) for English-speaking Africa and OAPI patent (OA) for French-speaking Africa.

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- **Patent classifications**: patent classification is a system for examiners of patent offices or other people to code documents, such as published patent applications, according to the technical features of their content. The International Patent Classification (IPC) is agreed internationally. the European Patent Office (EPO) and USPTO launched a joint project to create the Cooperative Patent Classification (CPC) in order to harmonize the patent classifications systems between the two offices.
- **Patent applicant/assignee**: when a person is applying for a patent, the word "applicant" refers to the assignee, the person to whom the inventor is under an obligation to assign the invention, or the person who otherwise shows sufficient proprietary interest in the matter. We call it also patent owner or patent assignee; typically, it is the inventor's employer.
- **Priority filling**: the first location in which a particular invention has a patent application filed, also known as the office of first filing.
- **Average family size**: average number of granted or pending patents in each patent family in an assignee's portfolio.
- **Geographic coverage**: the total number of granted or pending patents in Tier1 and BRIC regions or countries (Taiwan, Australia, Republic of Korea, China, India, Brazil, France, Germany, Japan, USA).
- **CAGR**: compound annual growth rate, initially used to calculate and determine the rate of investment return, it represents the average annual growth rate between two dates in the study.
- **Technical impact:** The technical impact is based on forward citations which are corrected depending on the nature of the citation (self/non self), the age and technical domain of the patent.
- **Portfolio value:** The patent value is based on technical impact and Geographic coverage. They are weighted and summed. The weight values have been calculated in order to give high scores to patents which have been litigated
- **Radicalness:** Calculated for each patent family and then average. Calculation based on the broad spreading of cited IPC/CPC subclasses.
- **Impactful patent** is the count of patent families with at least one non-self forward citation.
- **Interfering patents** is the count of patent families cited by an examinator for questioning the patentability or inventive of a patent application.
- **Category X:** Where a document cited in the European search report is particularly relevant, it is indicated by the letter "X" or "Y". Category "X" is applicable where a document is such that **when taken alone**, a claimed invention cannot be considered novel or cannot be considered to involve an inventive step.
- **Category Y:** Where a document cited in the European search report is particularly relevant, it is indicated by the letter "X" or "Y". Category "Y" is applicable where a document is such that a claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other documents of the same category, such combination being obvious to a person skilled in the art.

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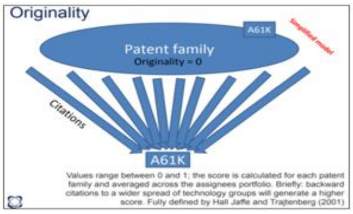

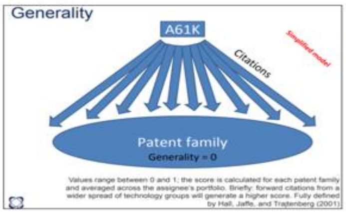

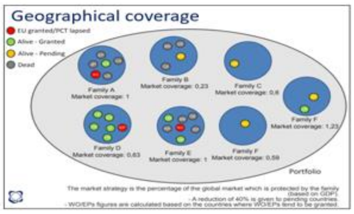

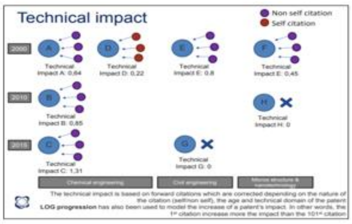

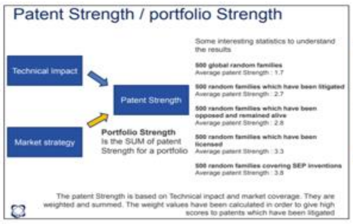

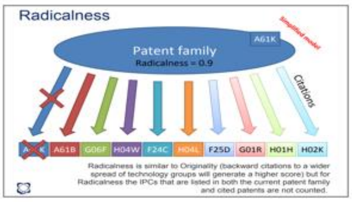

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Questel's Consulting team combines skills in IP, technology, and market to provide various kind of data-driven projects enabling innovative organizations to make strategic decisions: Patent Landscapes, Tech & Competency mapping, Patent portfolio assessment for pruning or licensing, Technology scouting, etc.

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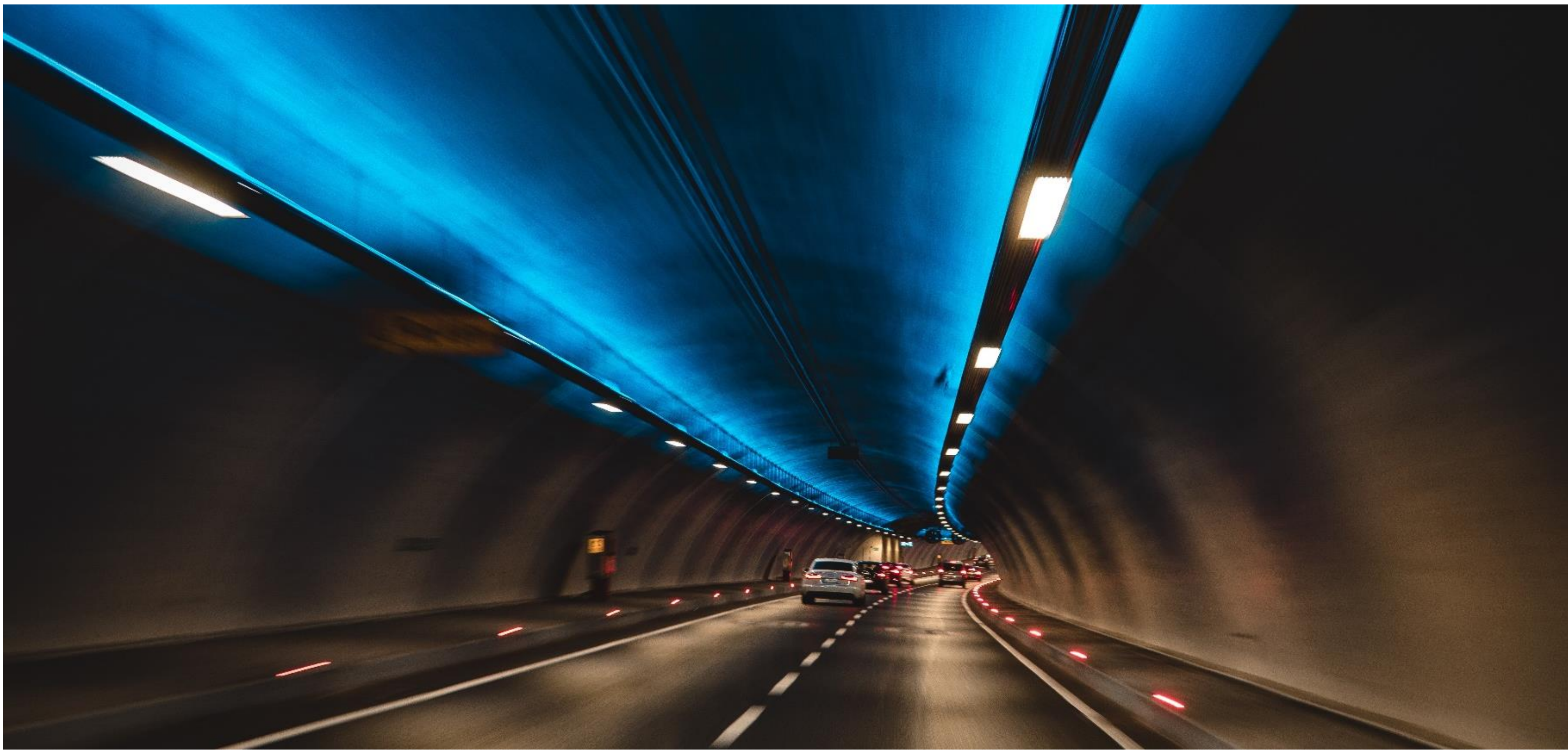

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